SCIENTISTS AND TECHNOLOGISTS
IN THE SPECIFICATION OF THE
PRODUCTION FUNCTION

BY

A. H. AZMY HASSAN

SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
UNIVERSITY OF EDINBURGH
1969

ACKNOWLEDGEMENTS

My greatest debt is to Professor J. N. Wolfe, whose deep interest in the theory of growth, economics of science, economic policy and regional development, etc., provided the main ideas upon which this study is founded. Without his most invaluable guidance and criticisms, and his unfailing support and encouragement, the completion of this thesis would not have been possible.

I am grateful to Professor P. Vandome. This thesis owes a great deal to his patience, scrutiny and criticisms in reading the earlier drafts as a whole and, in particular Chapter V. However, the points of weakness are mine.

The course of studies leading to the completion of this thesis was financed most of the time by a generous Scholarship from the United Arab Republic Government and the University of Ain Shams, to whom it is difficult to express my gratitude.

My thanks are due to Mrs.Russell, Mrs.McBride and Mrs.Williams who showed skill and patience in typing this thesis.

My deep appreciation is to my Wife. It is owing to her loving care for our child and understanding that I was provided the quiet and encouraging atmosphere in which to work.

LIST OF CONTENTS

CHAPTER IV (Contd.)

Physical Factors

CHAPTER XI (Contd.)

SUMMARY

Scientific and technological effort as measured by the main resources of scientists and technologists is regarded as an essential factor in technological efficiency. Their contribution to industrial production may be specified as three separate functions: research and development, on-the-shop-floor and scientific management. There is an obvious difference in the nature of activity as well as in the length of time during which each type of scientific effort is likely to pay off. It seems thus necessary to distinguish between scientific efforts directed at current productive activities and those devoted to investment in future technology.

From statistical point of view errors of omission in the specification of the production function are likely to result from ignoring the introduction of essential factors such as scientific effort as an explicit factor of production. Ignoring the correction for an incomplete adjustment of the studied units to the prevailing phase of the trade cycle is treated as an omission error on the grounds that the technical efficiency of all factors rather than the performance of capital alone is the one most likely to be affected by variations in the level of activity. Moreover, errors of specification in the measurement of the input factors are would to result from ignoring the heterogeneity of capital and labour. These errors of specification are likely to impart serious statistical bias in the estimated technological efficiency and in the estimated coefficients of the production function. Furthermore, they are likely to lead to unsound policy recommendations (see Chapter V).

The attempt made in order to avoid these sources of specification errors singularly and simultaneously provided, on the whole, consistent and statistically significant results despite data limitations. An appreciable part of the third factor of production or technical efficiency as estimated by the traditionally specified production function is explained when an account is taken of the vintage of capital, the structure of capital and

and the structure of labour, (Chapters VI, VII and IX). The results of correcting for the degree of capacity utilization and of the explicit introduction of: current, lagged and disaggregated scientific effort seem to be consistent with the desirable property of reducing the bias that is likely to result from errors of omission in the specification of the production function. (see Chapters VIII, X, and XI).

The model is applied to a cross-section of inter-industry in 1962, mainly on British and partly on Scottish manufacturing industries.

In order to carry out the present investigation a laborious attempt has been made to implement existing British data on 23 manufacturing industries. Net output has been interpolated between the years 1959 - 1962 inclusive. The Cambridge estimates of the Stock of all Fixed Assets, Plant and Machinery and other structures were further disaggregated. Modern and old layers of the vintage of: All Fixed Assets, Plant and Machinery and other structures were estimated for 1962. For Scottish manufacturing industries an estimation has been carried out for Gross Output, Net Output, Stock of All Fixed Assets, Plant and Machinery, and other structures of capital for 23 industries in 1962, (see Chapter IV).

CHAPTER I

INTRODUCTION

INTRODUCTION

A. In studying the factors contributing to and determining the rate of economic growth, the classical division into labour and capital (especially as conventionally measured) is increasingly regarded as providing inadequate explanatory variables because it does not allow for a proper treatment of technical progress. Increasing attention is also paid at present to the contributions which education, training, scientific knowledge, research and development and other forms of scientific effort have made towards technical progress and hence to economic development. New concepts and, consequently, new fields of interest made their appearance. From being treated as a "third" or "residual" factor, technical progress is introduced explicitly in ecnonomic models, often broken down into various components. "Investment in Human", "inventive innovative efforts", "Economics of research and development" and"Economics of Science" are just a few examples of the attempt to break down the "third" or "residual factor".

In addition to the traditional recognition of the social and political advantages of a well educated population, there is a growing awareness of the economic advantages of the transmittal of information, skills and learning.

Is it possible to isolate and quantify scientific knowledge? Can the requirements of research and development and scientific and technological manpower be determined to achieve set targets of economic growth? Howfar can we throw some light on the causes of economic growth and thus reduce the amount of our ignorance? It is one of the intentions of this study to evaluate the performance of scientists and technologists employed in various activities in manufacturing industry when they are treated as explicit factors contributing to industrial product.

The problem of explaining economic growth and differences in technical efficiency has generally taken one of two approaches in practices: The first approach has taken the line of regarding "residual growth" as reflecting "true technical change". Similarly, it considers differences in technical efficiency as indicating, among other things, successful inventive innovative effort. This approach leads to hypotheses concerning the behaviour of non-conventional factors of production which are introduced explicitly in the functional relationship. The second approach has taken the line of revising the measures of input factor of labour and capital so as to reduce the size of the residual by allocating parts of it to the redefined input factors. This approach involves allowing for some of the qualitative improvements as well as structural changes of the conventional input factors in order to eliminate sources of measurement bias. In its attempt to take account of qualitative aspects of conventional input factors, this approach meets some of the requirements of the first approach.

The lines adopted by the present study are a mixture of the two approaches.

Along the second approach, a revision is made in the measurement of the conventional factors of production in such a way as to avoid some of the bias introduced by aggregation, caused by ignoring qualitative aspects, or by leaving out of consideration the structure of input factors' activity. An improvement in measuring labour input is sought through considerations of variations in age/sex/skill structure and accounting for unemployment. In dealing with the measurement of capital input a deeper insight is gained by breaking down the aggregated stock of capital into the broad categories of plant and machinery, buildings and vehicles. Study is needed for the quality of capital and its role in economic growth. The recent tendency to regard the age-distribution of capital as reflecting the quality of capital is based on the assumption that newer capital is also "better" since it incorporates the latest technical improvements. The flow of capital services into the current productive process is not only a function of capital stocks quantity and quality but also of the degree of its utilization. Since there is no published data on the under and unutilized capital by industry, it is advanced that the introduction of a separate measure of the degree of capacity utilization is sufficient to correct, among other things, for capital utilization. Since the estimation of the third factor tends to be affected by whether or not the level of activity is regarded, then the explicit introduction of the degree of capacity utilization in the production function is regarded as belonging to the first approach.

Along the first approach, the "third factor" is regarded as mainly of an endogenous nature for which explanation should be provided. This will involve an explicit introduction of scientific effort as representing a significant part in "technological progress" and/or "technical efficiency".

It is advanced that the inventive-innovative efforts of Research and Development are largely dependent on the existence of a wide scientific base in managerial activities and on-the-shop-floor. The contribution of inventive-innovative effort is regarded as resulting from the allocation of scientific input between current and future output. In other words, the output at the current period is determined not only by current inputs, (including scientific effort), devoted to current output but also by scientific inputs from past periods which have been devoted to improving technology.

There are reasons to regard the employment of scientists and technologists on-the-shop-floor as the main form of scientific input that is allocated to current production. The evidence of similar investigations support the assumption adopted here that the employment of scientists and technologists in Research and Development is the main factor of scientific input that is devoted mainly to gaining a technological lead or catching up with technical leaders. It is, however, quite possible for some of the results of current Research and Development efforts to show up in current production. It is likely that a distributed lag of Research and Development is a suitable representation of its contribution to current and future production. The length of such a lag is dependent more on the industry or industries under consideration than on general 'a priori' grounds.

As a third form of scientific effort scientists and technologists in managerial activities are regarded as essential for industrial efficiency. A distinction between Scientific management and other forms of scientific effort is also important to improve the specification of the input of science and technology as well as being necessary to increase the accuracy of the production function specification. It is, therefore, advanced that Scientists and Technologists employed in management may be regarded as a suitable representative of the scientific management's input that can be introduced explicitly in the estimation of the production function. This direct way of evaluating an important part of managerial effort will be compared with the approach of the introducing of a firm Dummy variable in order to isolate the management contribution from the residual or technical efficiency. However, the firm dummy represents, in addition, the effect of other factors that influence the firm's product but are not regarded explicitly as factors of production.

Since one of the main duties of scientific management is to ensure effective efforts of Research and Development and on-the-shop-floor scientific efforts, it thus seems plausible to say that the contribution of scientific management is probably spread over current and future production.

From a statistical point of view, the bias encountered via errors of specification is regarded serious. However, emphasis in the literature has been placed so far mainly on the errors of specification resulting from omitting influential variables in the studied function. Such emphasis must not be undermined, yet due emphasis must be given to equally important sources of bias viz. errors of specification of variables' measurement. Both sources of specification error involve serious policy implications too. Therefore, the theory and practice of regarding various aspects of the pre-mentioned two approaches will be regarded from statistical and policy points of view.

Due regard is usually given to policy consideration in view of the fact that prediction is becoming increasingly important for running the economy on a national or regional basis. This practice is adhered to in the hope that this study becomes beneficial in practice. This tendency led to extending the application from British to Scottish manufacturing industries too.

It is regrettable that the word "regard" in the text should in many cases be read "consider".

B. Plan of the Work:

Chapter II sets a brief distinction between various forms of knowledge, indicates the importance of scientists and technologists to the vital needs of the economy. It also shows the need for planning the requirements of scientists and technologists. In evaluating the contribution of scientists and technologists to industrial product, a distinction is introduced between the main activities of scientific and technological effort in industry. The main assumptions, objectives and definitions are also advanced.

Chapter III provides a condensed summary of the work which underlines and forms the background to the present study.

In Chapter IV the task of describing data implementation and sources is undertaken.

Chapter V is meant to provide a link between Chapters III and IV and the proposed model in its general form. It also prepares for the gradual application of the model on British and Scottish manufacturing industries. The first section emphasizes the threat imposed by data heterogeneity for the appropriateness of the results of the investigation whose broad statistical and policy features are drawn by Section B.

Section B deals with the statistical and policy implications of the main sources of bias which result from errors of specifying the studied function as well as from the errors of sepcifying the variables involved. After a brief review of the previous work advanced by Chapter III, Section C formulates the present model in general terms so as to indicate the main features of the empirical work that will be gradually taken up by chapters VI - XI inclusive.

Chapter VI deals with the theory and practice of improving the measurement of capital through a distinction between its vintage.

In Chapter VII, improving the specification of capital is pursued further by observing a structural distinction as well as combining qualitative and structural improvements.

Chapter VIII regards the influence of disequilibrium in the level of activity on the performance of the economy. A combined treatment of the degree of capacity utilization and the qualitative and structural aspects of capital is provided.

Chapter IX considers the improvement of measuring labour through structural distinction.

In Chapter X the scientific and technological effort is regarded within the framework of productive activity. The theory is advanced that a measure of technical efficiency based on national product will be biased upward to the extent that output increases brought about by new and improved products, processes and techniques are not attributed to their main creators, i.e. scientific and technological efforts. A distinction between scientific and technological efforts aimed at current productive activities and devoted to improving future technology is made; also a distinction is established between three activities of Qualified Scientific Manpower on the basis of the type of work. These are research and development activities, scientific management, and on-the-shop-floor effort. Moreover, a set of assumptions dealing with the introduction of Qualified Scientific Manpower into the analysis, are put forward. Furthermore, an inter-regional study of research and development effort is undertaken. It may be of interest to state that Chapters VI - X inclusive provide applications on both British Manufacturing industries and Scottish manufacturing industries for regional comparisons purposes.

Chapter XI provides a condensed summary of the results and concluding remarks of Chapters VI - X. Moreover, Chapter XI pursues the study of scientific and technological effort in the British manufacturing industries alone since the relevant data on Qualified Scientific Manpower for Scottish manufacturing industries is not obtainable on an industry basis. In particular the scientific effort of management, on-the-shop-floor, the likelihood of a distributed lag of research and development effort, are considered. At the end of Chapter XI general concluding remarks are provided.

C. Limitations of the Study:

Three main limitations may be singled out here.[1] These are:-

(a) The limited extent to which problems of aggregation are dealt with.

(b) The lack of treatment of and test for simultaneous equations bias, and

(c) The dependence on estimated data to fill the gaps in the published data.

Firstly, inter-industry production functions are usually estimated on the assumption that all considered industries have the same production function and thus each shares the value of the estimated parameters with all others. This procedure is followed in this study despite its limitation.[2] However, this is not an inherent limitation of the inter-industry functions alone; it may also be shared, e.g. by inter-firm production functions especially for multi-product firms in which the different production processes use different skills and composition

---

(1) Other limitations are referred to in the text.

(2) This limitation is proposed by the evidence of inter-firm production functions which emphasize important and significant differences between industries.

of the labour force with respect to age and sex, and employ different vintages as well as different proportions of capital structure.

The point is that the most important danger which threatens the appropriateness of the estimates of the inter-industry production function in particular, is the aggregation bias. Although there is another expressed concern with respect to the appropriateness of the estimated coefficients for predicting the effect of increased factor input; it owes its existence to the detrimental effect of aggregation bias.

More than one approach can be devised to deal with aggregation bias. The one followed by this study is to deal directly with its main source. The set of factors which are mainly responsible for aggregation bias are mainly of an economic nature and have serious statistical and policy implications. They are dealt with theoretically in Section B of Chapter V. The steps necessary for correcting for them empirically are taken in Chapters VI - XI inclusive. In short they form the main features of the present model and involve:-

(i) Improving the specification of the main factors of production, i.e. labour and capital, and

(ii) Improving the specification of the aggregate production function itself.

Other approaches which deal with aggregate bias develops an aggregate production function whose coefficients may have built-in variability instead of being constant seems to be a tempting tool though it has not passed the experimental stage (e.g. Massel 1962). This method which intends to improve the estimated aggregate production function, (in the sense of reducing aggregation bias), derives such a function from the individual production functions of each constituent industry. A macro-production function can be obtained from individual production functions only if the latter functions possess certain essentially linear properties (Theil 1959). Broadly speaking, if linear micro-relationships are aggregated in terms of linear aggregates to a linear macro-relationship the resulting macro-parameters are weighted sums of all micro-parameters.(1)

No attempt is made to estimate the aggregate production function in the present study, along this line or to test for the aggregate bias, though it would have been desirable to do so. The main reasons are:-

(1) Data poses the greatest limitation

(2) Such an effort seems to warrant an independent enquiry.

Secondly, no attempt is made to test for or to avoid simultaneous equation bias through adapting particularly most efficient methods of estimation.(2) Time and data has not been sufficient to apply two interesting methods. The first is the Zellner version of the "Aitken generalized Least Squares". This method is designed to improve the efficiency of the estimated parameters of the single equation, as well as testing for aggregation bias. It requires the use of cross-sections of time series. The second method is the standard co-variance analysis which like the Zellner approach requires cross-sections of time series but it has the most desirable virtue of reducing to a large extent the simultaneous equation bias. Such bias means that the estimates based upon a single equation (such as the aggregate production function) are biased because this equation is a member of a system of equations such that the

---

(1) For each Macro-parameter there is one sub-group of Micro-parameters which play an influential role in the sense that its weights add up to 1, whereas the sums of all other Micro-parameters varies. Such favourite sub-group happens to be the one which corresponds in economic meaning to the macro-parameters considered.

(2) It is to be noted that the detrimental effect of many other sources of bias has been largely reduced or corrected for by this study, including managerial bias.

explanatory variables, as well as the dependent variable, are functions of the disturbance term in the given equation.(1) Apart from simultaneous estimates, (for which existing data are insufficient), the standard co-variance analysis seems to be most suitable for reducing the simultaneous equation bias in the present situation.

Thirdly, the fact that necessary data had to be estimated, interpolated and disaggregated may on the one hand be desired as an end whose achievement is welcomed and thus a source of blessing. On the other hand the great reliance on such implemented data is likely to impose a strain on the conclusions derived from the estimated relationships and on the degree to which these conclusions may be generalized. On the whole, the interpretations and conclusions drawn must be treated with caution and at best may be regarded as suggestive. It may be added that even the published data is hardly homogeneous in the strict sense. This fact is emphasized in data implementation and whilst appraising the comparability of data for inter-industry study as well as for other purposes, it is then pointed out that sampling technique, sampling units, coverage and definition may change from one source of information to another, from one region to another and from one time period to another. Nevertheless, it is a source of satisfaction that consistancy persists through the estimated relationships. Further, there is agreement between the aggregate production function estimated on the basis of published data and the aggregate production function which incorporate variables which are assessed by the present study.

---

(1) One of the main assumptions of ordinary least squares, the independence between explanatory variables and the residuals, becomes no longer applicable.

CHAPTER II

THE EMPLOYMENT OF SCIENTISTS AND TECHNOLOGISTS

THE EMPLOYMENT OF QUALIFIED SCIENTISTS AND TECHNOLOGISTS

After giving briefly a distinction between various forms of knowledge, this chapter proceeds to show the importance of scientists and technologists in speeding the rate of technological progress, increasing economic prosperity, guarding national security and improving the nation's trade in a competitive world.

Section "C" deals with the need for planning the requirements of scientists and technologists both in highly industrial and in developing economies. In section "D" an evaluation of the contribution of scientists and technologists to industrial product is introduced. Also a distinction between the main activities of scientific effort in industry is advanced.

In the remaining three sections the main assumptions of the model are introduced, the main objectives of the study are described and the important definitions are given respectively.

A. Technological Knowledge:

With few exceptions generations of economists regarded technological knowledge as a non-economic phenomenon determined externally. The "promotion" of technological knowledge from the rank of an exogenous, independent variable to that of an endogenous variable dependent on input and on the allocation of resources, is an important step. Not that this idea is a novel one. It goes back to Adam Smith, who wrote that "man educated at the expense of much labour and time may be compared to one of those expensive machines".(1) But never before our

---

(1) Adam Smith "An Inquiry into the Nature and Causes of the Wealth of nations", Everyman's Library, 1910, Vol. I, pp. 88-89.

time has the interest of economists and econometricians been so closely concentrated upon the analysis of economic growth and development. Thus it is not surprising that there is now such a burst of activity in the study of productivity of investment in knowledge. The focus of these studies is upon education, basic research, and applied technical research and development. The production of some types of knowledge is being regarded as an investment in the sense that it will pay off in the future through increased productivity.

There are, however, several other types of knowledge, besides those designed to pay off in the future. The most important of these is that complementary and needed scientific and technological knowledge in top executives and on-the-shop-floor. The knowledge implemented in such fields is not designed mainly to pay off in the future, but is meant to render immediate benefits, hence it may be regarded as current input factors.

Other types of knowledge are designed to give immediate utility and may be regarded as consumption types to the recipients. Society is allocating more and more resources to the dissemination of such knowledge. The printing of books, magazines, and newspapers, radio broadcasting, television, productions, etc., are examples.

B. The Importance of Scientists and Technologists:

Economic activity is concerned with the satisfaction of human wants, and technological progress permits these wants to be satisfied better than did pre-existing knowledge. Technological progress is mainly the outcome of innovated scientific effort and increased human intellect and experience. The production of new technology is itself an economic activity, for it represents in essence the mobilisation of society's creative energies to reduce scarcities more than the existing resources and products can. It seems essential thus to evaluate the effectiveness of such a reputable element in the economy's creative energies as scientific, (natural and social), and technological manpower.

The appreciation of scientific effort is being increasingly regarded as not only a guaranteed way to speed up the rate of technological and, consequently, economic advance, but also a condition for survival in a competitive world. A country can achieve a higher standard of living either by increasing the rate of exploitation of its natural resources or by improving the manner of that exploitation so as to fulfil human needs at less cost. One of the ways of achieving the latter situation is to intensify scientific effort, i.e. mainly to improve the manner of the exploitation of the natural resource of brains to supplement (or to make up deficiencies in) other resources.

Moreover, technological progress and investment in human intellect become increasingly attractive to both researchers and policy makers primarily because the growth of per-capita Gross National Product, and also in advanced economics, military power, has been placed high on the priority list. Towards that end large public and private outlays on Research and development and on elaborating human capacities have been allocated.

C. Planning the Requirements of Scientists and Technologists:

In highly developed countries interest in the requirements of manpower in general and in scientists and technologists in particular, has arisen because of the attendant need for government investment in the expansion of educational facilities and because of the shortage of scientific and technological personnel which has developed because the demand for them has risen so dramatically in industry, government and trade, etc. Emphasis on the planning of at least some aspects of each nation's economic development has focussed attention on the manpower requirements which have to be planned for. In developing countries the concern with manpower requirements has reflected recognition that the provision of skilled workers has to go hand in hand with the introduction of new industries or advanced industrial processes. Modern medical care, efficient government administration, and considerable educational improvement requires highly trained personnel, teachers and educational administration. It is thus likely that technology and economic growth can largely be impeded in any country by shortages in the supply of highly skilled personnel in relation to vital needs. Of course it is evident that surpluses in certain types of disciplines does not compensate for the above-mentioned shortages, since the market mechanism does not respond to short-term disequilibria.

A carefully planned educational system should provide a flow of graduates in each discipline to meet the growing needs of various sectors. A balanced number of technicians and supporting staff should also be made available in order to make best use of the effort of highly qualified personnel. Further, the educational system should take the responsibility of increasing the quality and skill of the labour force. Furthermore, public training centres, and on-the-job training, together with educational efforts should be co-ordinated with the view of bringing about highly trained manpower.

D. Evaluating the Contribution of Scientists and Technologists to Industrial Product:

As a result of the fundamental importance of scientific effort to national growth andtechnological advance, there has been a growing interest in evalua-ting its contribution to national growth in general and to industrial product in particular. The main emphasis has been towards one aspect of scientific effort, namely Research and Development effort, and on some of the results, (or inventive-innovative output), namely number of patents and major individual innovations. Otherwise all types of scientific effort have been implicitly regarded as components of technological progress and assumed to be embodied in capital formation.

The present study, which favours an explicit measurement of scientific effort as a whole and as broken down to its main industrial functions, does not exclude the liklihood that part, but only part, of scientific contribution may be incorporated in new and improved capital. In other words the view is advanced that it may be possible at least in theory to evaluate the contribution made by scientists and technologists in a form that can be related to measured industrial product. Ignoring scientific effort in management, on-the-shop-floor and in research and development makes it likely that measured technological progress (or technical efficiency) may be biased upwards to the extent that output increases brought about by new products, improved processes, production and management techniques, etc. are not attributed to their main creators.(1) Thus it seems appropriate to study scientific effort within the framework of productive activities and to distinguish between the main functions of

---

(1) In an economy wide study a fourth function, namely education may not be disregarded.

scientific personnel.

The distinction between the three activities of scientific effort is based on logical grounds. In addition to the fact that the nature of work performed by each is different, lags of various length (or a distributed lag) seem likely for some scientific activities whilst for others this is not so. The time lag involved in the case of pure research is relatively longer compared with the lag needed for development. No such lags are expected to delay the contribution of scientific effort both on-the-shop-floor and in managerial activities. Moreover, it is desirable to evaluate the relative contribution of each type of activity to the productive process.

The rationale for distinguishing among scientific functions may be summarised as follows, inventions are created in the research and development stage. Unless these inventions are innovated they may bear no direct effect on technological progress. An indirect effect is the increase in the stock of knowledge which may be of use one day, and another is the increase in the experience of the scientific persons involved.(1) Innovations are made easier and more rapidly in the production department if there is a sufficient amount of Scientific Manpower on-the-shop-floor who appreciate the significance of research and development output and manage its application. The original decision to commence research and the co-ordination of the whole process has to be controlled by a scientifically appreciative minded management. Such management has sometimes to choose amongst a range of alternatives or take the responsibility of assessing the commercial and growth potential of a given invention, or research and development project.

---

(1) Other effects may be exerted on the cost of solving already perceived practical problems and the more advance in the knowledge may generate searches for problems that knowledge could be applied to.

E. Assumptions:

The following are the main assumptions:-[1]

(i) All capital formation incorporates the most up-to-date production technique. Modern layers of capital, and in particular, modern layers of plant and machinery are thus regarded as more efficient than old layers of capital and/or plant and machinery. A great degree of flexibility is thus introduced by regarding a distinction between modern and older type of capital (and/or plant and machinery). In theory, the homogeneity requirements would necessitate a distinction between each vintage of capital and the next, because this year's capital is by assumption superior to last year's capital. Pursuing the homogeneity requirement to its logical conclusion would mean that a separate production function (which may be called a vintage production function) should be formulated to describe the output producable by a given vintage of capital and the labour necessary to man it.

(ii) The coefficients of the production function are homogeneous across industries.

This assumption is made, in spite of its limitation, because the data available on scientific and technological personnel is appropriate for estimating inter-industry functions.

---

(1) These assumptions relate to the main structure of the study. Some more assumptions are made to allow data manipulation which will be no longer necessary if the required data is made available and comparable.

More specific assumptions are made with respect to the employment of Qualified scientific manpower in productive activities (see Chapter X.)

Although it is likely that this assumption introduces some aggregation bias, the steps taken to avoid erratic specification of input factors and the incomplete specification of the aggregate production function should reduce this bias,(See pages 8 and 9).

(iii) The degree of capacity utilization is measured by the ratio of numbers in employment to insured labour. This assumption is imposed by the data available. Amongst the alternative measurements of the degree of capacity utilization, it seems that there is no empirical evidence to prefer any over the others (See Brown, 1967). However, the limitations of this assumption is regarded in Chapter VIII.
Also the possibility of its relaxation is considered.

F. Objectives:

The main objectives of this study are:-(1)

(i) An evaluation of the relative contribution and effectiveness of each one of the main scientific functions on the productive process, together with an evaluation of the effect of both current and lagged investment in technology.

(ii) The development of an empirical method of dealing with the vintage of capital which recognizes existing data limitations and is appropriate from the point of view of policy consideration.

---

(1) For other desirable objectives which may be achieved on the basis of micro data see appendix to Chapter II.

(iii) An improvement in the specification of capital via the introduction of a distinction between various structures of capital and between different vintages of capital.

(iv) An improvement in the specification of the aggregate production function through an allowance for variations in the level of activity.

(v) An improvement in the specification of labour via a distinction between labour's age/sex structure as well as a distinction between various qualities of labour.

(vi) An investigation into the result of breaking down the residual term which is generally known as technical efficiency, technological progress, or the third factor of production through:-

 (a) The introduction of scientific effort as a current factor of production and as an investment in future technology.

 (b) The improvement of the specification of the measurement of capital and labour and of the aggregate production function.

(vii) A consideration of the statistical and policy implication of ignoring various sources of bias.

G. Definitions:

(a). Qualified Scientific and Technological Manpower:

What is meant by Qualified Scientific Manpower? Is it meant to refer to the handful of brilliant geniuses in a given economy, to those with doctoral degrees, to those with some acquired or developed skill? What characterizes "specialized talent?" It has been pointed out that the category called "specialized" or "scientific" or "professional" is much easier to illustrate than to define, Cole (1957).

An investigator in this field, especially if he is to rely on some available source of information, may be limited by the existing system of calssification which may add to the confusion of failing to take into account the most recent and ever changing trends of specialization and the appearance of new subject fields. Those limitations must not be ignored in any attempt to reconcile widely conflicting estimates of the number of highly trained personnel.

Further difficulty arises when the concept of specialization undergoes a change of definition. What was once a specialized skill might be considered unskilled or semi-skilled now. Time and place has much to do with the hierarchy in any job classification. The nature of the job required, the characteristics of the person performing it, or the complexity of the product or service involved are factors in continuous flux, making it difficult to reach a universal definition of scientific personnel. Nevertheless it may be asserted that any acceptable definition of QSMP should be a dynamic and flexible one to allow for trends both in the educational system and in the type of work undertaken by Qualified Scientific Manpower.

It is noteworthy that the definition of Qualified Scientific Manpower provided by the first triennial survey of 1956 has changed twice, once in the 1959 survey and again in 1962, the present study will follow the definition provided by the third triennial survey.[1] The 1962 survey defined Scientific Manpower to include all professionally qualified scientific and technological manpower available for employment. It thus covers university graduates in scientific and technological subjects; holders of certain other awards of comparable status, such as the Diploma in Technology, and associates of all those institutions for higher education, and corporate and graduate members of those professional institutions which are listed in Appendix A of that report. The reason for adopting this definition is primarily to draw on the survey's pool of information and also to attempt to reconcile the information provided by other surveys with the 1962 survey in order to assess comparable figures of Qualified Scientific Manpower.

Qualified Scientific Manpower is sometimes refered to as Scientists and Technologists, scientific talent, scientific personnel, and highly qualified personnel. The input of scientific manpower is inter-changed with the inventive-innovative effort and scientific effort.

(b). Research, Development, Design and Production:

A dangerous misrepresentation of various aspects of a firm's activity arises if no clear distinction is drawn between research activity and other related scientific activities such as routine testing and scientific information services. Also, a "cut-off point" between development work and production must be established. This distinction is necessary to improve the accuracy and comparability of information on scientific effort information and thus to avoid misinterpretation of the data.

---

(1) D.S.I.R. Report 1956
H.M.S.O. Comnd. 902, 1959; and Comnd. 2146, 1963.

An overstatement of research and development activities would arise from the inclusion of "related scientific activities". It may be a source of convenience that the Frascati Manual has laid down comprehensive guide-lines.(1) Proposals were made by the Manual for a "three stage" system of measurement whereby respondents would give more serious thought to the problems of distinguishing between the three stages and render more precise returns. Such returns should provide total expenditure and manpower on all activities, an explicit account of non-research functions, and the appropriate amount for research and development work which may be carried out in other departments to which the research unit may be attached (e.g. development work in production shops in the case of the research department of an industrial firm). The Manual recommendations are:-

> "If the primary objectives are to work further improvements on the product or process, then the work comes within the definition of Research and Development. If, on the other hand, the product or process is substantially "set" and the primary objective is to develop markets or to do pre-production planning, or to get the production process going smoothly, then the work is no longer Research and Development".

Applying the Frascati definition the design, construction and testing of prototypes normally falls within the scope of Research and Development. This applies whether only one prototype is made or several and whether consecutively or simultaneously. But after the prototype(s), with any necessary modifications have been satisfactorily tested, the costs of the first trial production runs cannot be attributed to research and development as the primary objective is no longer further improvement of the product, but getting the production process going.

---

(1) Frascati's Manual, paragraph 2.3.

The first units of a trial production run for a mass production series should not be regarded as research and development prototype, even if they are loosely described as "prototypes".

It is also difficult to draw a distinction between research and development. Still more difficult is the separation of basic (or pure) research from applied research, and to sub-divide development, e.g. into explanatory and specific Development. All these division lines have not yet achieved a wide recognition mainly because distinctions that fit the situation of one industry do not fit the situation of others. Research and development refers more typically to the process of technological innovation: creation, application and diffusion. Scientific findings and technological inventions would require technological development for practical, chiefly industrial, application. The twin term of research and development is, however, a poor one, for it is not research that is developed; instead the findings of Research together with existing stock of knowledge, technological possibilities, and innovation, are developed for use in production.

Development is the systematic use of scientific knowledge directed toward the production of useful raw materials, devices, methods, systems or processes, exclusive of the design and development of prototypes. In contrast to applied research which is designated "investigation", Development is called "technical activity" especially that directed to non-routine problems which are encountered in translating research findings and general scientific knowledge into new and improved products and processes. Raw inventions have to be further developed before they can be usable. It is usually a long way from sketching how the invention is supposed to work, to the blueprints and specifications for the construction of the productive facilities. This long way involves experimentation, design and development of prototypes, scale models, testing, the construction of pilot plants, studies for use of pilot-plant experience in large-scale production, and a great many new problems, new solutions, redesigning, retesting, etc., at every step of the process. When development designates the sum total of all the steps taken between invention and production, it becomes a little easier to determine where it begins, especially if the invention is patented, so that the patent application marks the end of invention work and the beginning of the Development activity. Tests and evolutions do represent a sizable and probably increasing share of total research and development experience. They must be incurred before anyone may introduce any of the technological novelties in the actual production programme. The tests are not routine checks within the production process; they are the "final examination" which the candidates for innovation, for introduction in production, must pass in order to demonstrate that the development process has been successfully completed, and thus are an integral part of development and their costs are a legitimate part of research and development expenditure.

The basic criteria for distinguishing basic research from applied research is that the former creates basic knowledge on which practical, applicable knowledge may rest but which itself is too general, too broad or too deep, to have direct application, whereas applied research creates directly applicable knowledge.(1) As far as industrial firms are concerned basic research projects represent "original investigation for the advancement of scientific knowledge ... which do not have specific commercial objectives, though they may be in fields of present or potential interest to the reporting company".(2)

---

(1) F. Machly "The Production and Distribution of knowledge in the U.S." Princeton University Press, 1962.

(2) Vonnevar Bash, "Science, the endless frontier". A report to the President, Washington, 1945.

Research undertaken by industrial firms should be presumed to be applied research. Because of the abstract nature of basic research and because of an element of arbitrariness in the identification of the borderline in the area between basic and applied research, firms are guided by their own interpretation. Only very few giant corporations in the United States are known to have basic research departments. Moreover, researchers in such departments are inclined to become patent-minded within a few years of their commencement. Applied research is being restricted to research projects which represent investigations directed to the discovery of new scientific knowledge and which aim at specific commercial objectives with respect to either products or processes.

Qualified scientific manpower employed in research and development is sometimes referred to as research and development personnel, creative personnel, creative ability, or research and development team.

The input of qualified scientific manpower engaged in research and development is sometimes refered to as the research and development effort, scientific effort in research and development, or scientific effort devoted to improving future technology.

No distinction is made by the present study between scientific and technological personnel engaged in the research and development activities. The numbers employed in research and development are taken from the triennial scientific and technological manpower surveys (apart from the introduction of some necessary corrections described by Chapter IV).

Qualified scientific manpower engaged in the production department is sometimes refered to as scientific personnel on-the-shop-floor.

The input of qualified scientific manpower on-the-shop-floor is sometimes refered to as scientific effort on-the-shop-floor.

The numbers of qualified scientific manpower employed on-the shop-floor are provided by the triennial scientific and technological manpower surveys (see Chapter IV).

APPENDIX TO CHAPTER II

Unrealized but still desirable objectives:

(i) An assessment of the most desirable technical coefficient of the main function of scientific effort as a guide to future requirements of Qualified Scientific Manpower.

The most desirable technical coefficient of Qualified Scientific Manpower is defined as the output elasticity with respect to the Qualified Scientific Manpower as estimated by an inter-firm (or time-series of inter-firm) production function which is estimated on the basis of those leaders in technical efficiency and/or technological progress if they are the most efficient (and/or the fast growing). This objective can be achieved provided that a reasonable range of inter-firm performances is available. Those firms in a given industry which are the most technically progressive or most efficient at present may be regarded as indicating the performance for an average firm in the near future. The requirements for Qualified Scientific Manpower of those leaders in technical advance and efficiency, estimated for the present are the best guide to the future requirements for Qualified Scientific Manpower of an average firm in the near future. The implicit assumption is a gradual movement of the backward and less efficient firms towards the performance of the leaders in the field imposed by survival needs. Those leaders are usually referred to as the best practice technique group of firms whose -

(a) Capital equipment,

(b) Human intellect,

(c) Production Technique,

(d) Fuel, raw materials and components.

incorporate the latest know-how.(1)

This gradual movement assumption implies that the shape of the future requirements of Qualified Scientific Manpower in a given industry will be largely indicated by the present best practice employment of Qualified Scientific Manpower adopted by the most technically progressive-efficient firms. Thus the industry will be moving from the present norm of employing Qualified Scientific Manpower at time t to a new level at time $t + p$. The former average level is given by the estimated output elasticity with respect to Qualified Scientific Manpower of all firms as given by the estimated production function. The future level will be estimated by the product of:-

(a) The most desirable technical coefficient of Qualified Scientific Manpower as estimated by output elasticity with respect to Qualified Scientific Manpower employed by the most technically progressive-efficient group of firms

and

(b) The predicted output level at a future date that is compatible with the industry's characteristics.

---

(1) It follows that the "ideal" path of technological progress is that which will result if new technological innovations are always adopted by all productive units the instant they are developed. In practice, however, due to incalculable factors this does not happen, e.g. managerial ability, initiative and drive does vary. There is no homogeneity in the capital labour and all other inputs used, industrial secrecy and own technological knowledge and innovations are not allowed to go easily to competitors ... etc. The result is a prevailing state of art and technology. The actual Technological Progress must represent in some sense a weighted average of the best practice technique and other techniques in use, the weights being often suggested to be related to the amount of investment in each vintage of capital. The weights should also be based on various levels of human intellect. In that case the actual Technological progress will be assessed according to the notion of technical innovation that is embodied in capital goods and in human intellect.

The difficulty with achieving this objective in an inter-industry analysis is obvious. It may be largely acceptable to assume that firms in a given industry tend to follow the steps of the leaders in their field. However, it is hardly convincing to argue that backward or slow-growth industries tend to follow the steps of the most progressive ones. This is mainly because industries vary in their scientific orientation and their technological requirements. Also they vary in the degree of competition and the average size of the firm.

Moreover, the less progressive industries may not be able to follow the steps of the scientifically oriented ones. They are likely to be tied to the technological development of their own industries. This, of course, does not exclude the possibility of the spill-over effect from the technological development of one industry to another.(1)

It is to be expected that the greater the intensity of technological invention-innovation, scientific orientation, degree of competition, or rate of growth, the shorter is the period of adjustment to the most desirable level of Qualified Scientific Manpower.

(ii) The development of a sophisticated method of projecting the demand for Qualified Scientific Manpower.

This objective is closely related to the previous one and may be

---

(1) Studies relating productivity increases to Research and Development may suffer from conceiving of Research and Development as mainly directed at cost minimizing. It may be that Research and Development is directed at the establishment of temporary monopoly power through the introduction of new products. (See E. Gustafson p. 184). One industry's (or firm's) new product is frequently another industry's (or firms) cost-reducing improvement. In many industries significant improvements come about through the Research and Developments efforts of suppliers and customers of the industry rather than through the efforts of the industry itself. In the extreme situation where an industry's Research and Development effort is mainly spilled over other industries, no direct correlation between productivity change and Research and Development may be found.

confidently applied to an inter-firm study. The main requirement for such a development is the constancy of output elasticity with respect to Qualified Scientific Manpower. If the constancy hypothesis is rejected then the future requirements of Qualified Scientific Manpower will not only be dependent on output growth but also on the expected tendency of the output elasticity with respect of Qualified Scientific Manpower.(1)

Use must, thus, be made of the concept of the most desirable technical coefficient discussed in (i).

(iii) An investigation into the relationship between size, the employment of Qualified Scientific Manpower, the inventive-innovation output of Research and Development and the technical progress-efficiency of the studied firms. In view of the immense study of this issue in the American economy, similar effort is required to be undertaken on the British economy. Again a comprehensive set of data on firms is necessary to the application of this study.

---

(1) The gap between the leaders and the followers in the employment of Qualified Scientific Manpower is mainly due to two reasons; firstly a higher density in those fields which are largely regarded as science fields; secondly, an initiation of employing scientists and technologists by the leaders in what is not yet traditionally regarded as science fields as in executive and administrative positions. Following the steps of the leaders may establish a trend of employing more and more of those with scientific background. If such a trend continues a tremendous increase in the demand for scientific manpower is likely to result. An indication of such a trend is expected to be shown by the most desirable technical coefficient of Qualified Scientific Manpower. It may be one of the reasons why the constancy assumption may have to be rejected. Moreover, the balance between the employment of Qualified Scientific Manpower in various functions may change giving yet another reason why the constancy assumption may be rejected. This change in the balance may occur if what is stated by some firms as "the long-term demand for Scientific Manpower" becomes an established practice*. They pointed out that future automation of production processes would enable them to increase their research effort at the expense of Qualified Scientific Manpower now engaged on production. Future automation for some firms may be at present already applied by most progressive-efficient firms and may as well be reflected in the most desirable technical coefficients of the Research and Development activities and on-the-shop-floor activities.

*H.M.S.O. "The Long-Term Demand for Scientific Manpower", 1961.

(iv) Given the supply function of the production resources and the demand functions for products, the use of inter-firm data to assess an industry's production function provides an answer to a more general question, namely what is the optimum combination of input factors for that industry at a given time.

An answer to such a question would provide a valuable managerial guide for efficiency and progress decisions. The production function coefficients of a given industry indicate the combination adopted by an average firm. The use of a best practice production function, i.e. one estimated from observations belonging to the most efficient production units would make it possible to estimate the optimum combination for an average productive unit of the best performance group.

CHAPTER III

PREVIOUS WORK

PREVIOUS WORK

An attempt to review the previous work relevant to the present study could be extended to cover models which deal with such topics as economic growth, technological progress, productivity, theory of production, cost analysis theory of capital, learning by doing, education, technological innovation, research and development and economics of science, amongst others. It is to be noted that the attempt to consider the previous work here is no more than a sketchy one. Further elaboration will be given in the text of the work where felt necessary.

In this brief survey the following aspects of the previous work will be regarded:-

A. The treatment of technological progress in growth models,
   Technological progress used to be regarded as wholly exogenous to the economic system; embodied in newly produced capital equipment, or attributable to human experience.

B. Discovering the components of technological progress,
   Technological progress in the gross sense is known to represent the influence of a set of factors (see below) amongst which is technological innovation, which is known as technological progress in the narrow sense. The interest in uncovering the contents of technological progress in the gross sense arises from the need to discover sound means of speeding technical advance and economic growth.

C. Investigating the determinants and the results of technological innovation.

D. Production Functions in Theory and Practice.

A. Technological Progress in Growth Models:

(a) Technological progress regarded as exogenous to the economic system,

With few exceptions, generations of economists regarded technological progress analytically as an exogenous variable. Its precise linkage to economic growth was not all that obvious and thus was treated as a non-economic phenomenon determined externally. There undoubtedly is some exogenous component in technological progress, but there is also an endogenous one. However, this fact was recognised long ago, e.g. by Smith (1910); Marx (1909); Mill (1868); Marshall (1916), and Hicks (1932). More recent evidence indicates that the endogenous component is by and large the dominant one (see below). The models which regarded technological progress as exogenously determined usually measured it by an exponential function of time, Solow (1957).

(b) Technological progress regarded as embodied in capital formation,

When attention is turned to economic growth, many economists found it natural to suggest capital formation as its chief cause and the main variable internal to those models that would allow output to rise. Thus the then novel concept of embodied technological progress found its way into growth models. Harrod (1948) advanced that a steady output growth may be achieved by (neutral) technological change.(1) A prerequisite condition is that technological progress would require additions to capital in the form of new investment.

---

(1) Neutral technical change is neither labour saving nor capital saving, i.e. it leaves unaffected the rate of substitution between both labour and capital.

These models incorporated technological progress as a function of:-

(a) accumulated production, Wright (1936)
(b) time, Solow (1957)
(c) investment rate, Kaldor (1961)
(d) rate of change of investment, Kaldor (1962)
(e) accumulated gross investment, Arrow (1962, III)
(f) time and investment rate, Eltis (1963)

Solow (1957), and Massell (1960) were primarily interested in separating the proportions of the total increase in output per man hour that is caused by growth in capital stock from the increase brought about by technological progress. These studies seem to have turned away from capital formation as the main source of growth to technological progress as the only important factor under the assumption of neutral technical change. Solow's conclusion is that technical change is neutral on the average and that there was little basis of choice, according to the data he used, among five possible production functions, and that about 87.5% of the increase in gross product per man hours is attributable to technological progress and 12.5% to capital deepening effect. Massel's findings are 84% and 16% respectively. His conclusion is that there is a great need to shift the emphasis from the theory of capital to the theory of technological progress as an explanation of the growth in aggregate output.

In another paper Solow (1959), in line with Johansen (1959), indicated that since technological progress only occurs when the capital used embodies the new technology, capital formation is important to make use of new methods. He further implied that increasing investment is necessary for technical diffusion, adding that the growth rate can be increased by increasing investment because this lowers the average age of capital goods, thus cutting down the average lag between the development of new methods and their widespread use.

(c) Technological progress regarded as embodied in human experience,

Studies relying on the assumption that all technological knowledge is embodied in capital formation are at the other extreme from those studies which emphasize human experience as the main cause of technological progress. Niitama (1958) fitted a regression model of production for industry in Finland and found that most of the output increase was attributable to the passage of time, and little attributable to capital formation. He concluded that emphasis should be taken away from capital as an aid to economic growth and placed, not in addition to but instead, on the human factor. However, Niitama's conclusion had been reached and verified long ago by aeronautical engineers. T. P. Wright (1936) studied the role of experience in the airframe industry. He found that the number of man hours expended in the production of an airframe is a decreasing function of the total number of air frames of the same type produced. This relation has become one of the basic factors in production and cost planning techniques.

This phenomenon was subsequently investigated by others and given the names - "learning curve", "progress ratio", "horindal effect", Lundberg (1961); "Learning by doing", Arrow (1962(III)); and "progress function" Alchian (1963). It is defined as the function which describes how average and marginal input requirements are related to accumulated output up to some point in the production run. The volume effect is rationalized by better organization, learning and experience on the part of both labour and management, in short by an improvement in human ability.

Wright (1936) estimated separate progress functions for each input so that several progress functions applied to the overall production of airframes. Hirch (1952) found similar evidence for the production of other machines. Verdoorn (1949) applied the same function to national product under the assumption that output is increasing exponentially, i.e. current output is proportional to cumulative output. The latter is used to explain labour productivity. Alchian (1963) estimated progress functions for data on Second World War production of airframes. He found that rates of progress differed significantly across plants that were producing similar makes of fighters and bombers. Lundberg (1961) found that the productivity of the Horndal Iron Works in Sweden had increased on the average by 2% per annum though no new investment had been undertaken for a period of fifteen years. Such a striking steady increase in performance can only be imputed to the learning effect.

Empirical studies based on progress functions have mainly dealt with the production of heavy durable capital goods where the production run of the same type of product continues for some time. Changes in product design or description in the flow of output lead to positive deviations in the marginal labour requirements above the estimated progress function. Although all estimates were statistically significant, the fitted progress function as discovered by Alchian(1963) were of only limited value in predicting future labour requirements. The instability and limited reliability of the progress functions suggest that if learning is the underlying causal force it does not operate in a smoothly predictable manner.

Arrow advances the hypothesis that technological progress in general can be ascribed to experience, i.e. the very activity of production gives rise to problems for which favourable responses are selected over time. Cumulative output is not suitable as an index of experience since the stimulus to learning would appear to be constant for a constant rate of output. Instead he used cumulative gross investment because the introduction of each new machine is capable of changing the environment in which production takes place, so that learning is taking place with continually new stimuli.

Nevertheless, Arrow does not seem to be ready to compromise between the advocates of human factor origin of technological progress and the supporters of capital embodiment of technological progress. He kept an extremely restrictive assumption, namely that new capital goods incorporate all the knowledge then available, but once built, their production efficiency cannot be altered by subsequent learning. It is the same one adopted by Solow (1959), Johansen (1959) and Massel (1960) who envisaged substitution in the ex-ante sense only. This seems to be the dividing line between the two lines of thought. The advocates of the learning process affecting the ability of the human factor adopt the other polar assumption that alternative capital-labour ratios are possible both before and and after capital goods are built. However, both lines of thought did not extend their models to take account of the fact that learning takes place not only as a by-product of ordinary production but also through institutions, education, research and development and other forms of scientific effort.

The present model regards as unsatisfactory and unduly restrictive an assumption which regards technological progress as wholly:-

(a) disembodied or organizational,

(b) embodied in new capital equipment, or

(c) attributable to human experience.

The present model accepts instead that part but only part of technological progress or technical efficiency is incorporated in newly produced capital. Also education, training and human experience are components of technological progress (or technical efficiency). The model advances, further, that an appreciable part of that technological progress (or technical efficiency) is attributable to scientific effort as an input factor influencing current and future production activities.

B. <u>Discovering the Components of Technological Progress In the Gross Sense:</u>

It is becoming increasingly important to investigate thoroughly the constituents of the third factor. It is indicated above (see pages 2 - 4) that in the previous work the attempt to break down the third factor took either one of two lines. The first regarded technological progress as an endogenous variable which should be explained in terms of non-conventional factors of production. In the second line, revising the measurement of conventional input factors is resorted to in order to reduce the size of the residual by allocating parts of it to the redefined input factors. It is also indicated that the line adopted by the present study is a mixture of the two approaches and a brief introduction to the empirical work is provided.

Technological progress in the gross sense as defined by Domar (1961) is composed of:-

(a) technological progress in the narrow sense (technological innovation);

(b) economies of scale;

(c) external economies;

(d) labour improvements (health, education, skill);

(e) better management, and

(f) improved product mix.

In a pioneering empirical study into the sources of growth in the United States for the period 1929 - 1957, Dennison (1962) attributes 48% of growth to increases in conventional input factors and breaks down the residual 52% into: 23% increased education, 9% economies of scale, and thus leaving only 20% to be explained by technological progress.

Butler (1964) summarizes Dennison's results and similar work to show that the United States growth is explained by:-

	%
Increase in the quantity of labour	16
Increase in the quantity of capital	15
Increased intensity of work	2
Efficient use of materials	5
Better quality capital and other factors ...	9
Economies of scale	9
Better allocation of resources	4
Better quality of labour	21
Increase in the formal education	8
Increase in on-the-jop training	11
	100%

Thus 9% is the residual which could not be allocated to specific factors. It includes such factors as the increasing efficiency of machinery, improved management techniques and the contribution made by research and development and other scientific efforts.

C. Investigating the Determinants and the Results of Technological Innovation.

One of the contents of technological progress in the gross sense, is technological innovation. It has attracted the attention of recent investigators in their attempt to determine more precisely what constitutes technological progress. It is defined as the introduction of new and improved processes, designs and products. Technological innovation was first advanced by Schmpeter (1936). His main hypotheses are that the position of accumulated monopoly rewards, the prospects of additional such rewards in the future, and the security attending market power are prerequisites to undertaking the risks and uncertainties of innovational activities. He defined innovation broadly enough to include, among others, mergers, new organizations, new advertising campaigns, new products, and new processes. Only the last two are the direct consequence of scientific effort on the productive process. However, his assertion that a business structure consisting of monopolies will progress more rapidly than a competitive society has been vigorously disputed on the grounds that monopolies tend to become stagnant and unprogressive, and more importantly that historical studies fail to reveal any special tendency for major advances to emanate from monopolistic firms.

The empirical investigation of the case for bigness will be regarded first then it will be followed by considering determinants versus results of technological innovation, total productivity, growth of firms and industries and technological leadership and the speed of diffusion.

(a) The case for bigness:

Markham (1962) states that in 1961 an estimated 11,800 manufacturing and other companies in the United States performed research and development; a smaller number financed research and development out of their own funds. 391 companies employing 5,000 and over account for only 3% of the total number of companies performing research and development, and for an insignificant 1/100th of 1% of the number of all industrial companies, but they accounted for slightly over 80% of the total company-financed research and development. This may be viewed against the finding that in 1958 the 478 companies employing 5,000 and over accounted for 29% of total industrial employment and 26% of total sales. Companies having less than 1,000 employees accounted for 90% of the total number of companies and for 66% of total industrial employment, but for only 5% of total company-financed research and development.[1]

Five industry groups containing most of the narrowly defined industries making up the "oligopolistic" core of United States industry accounted for nearly 75% of all privately financed research and development: chemical and allied products 19%, electrical equipment and communications 19%, motor vehicles and other transportation equipment 14%, machinery 13% and aircraft and missiles 8%. At the same time there are several examples of highly concentrated industries such as tobacco products and steel that rank low in research and development. Similarly some of the firms included among the largest 500 corporations spent a relatively small percentage of their sales on inventive-innovative activities.

The statistical results obtained by Hamberg (1964), F. Scherer (1965) (I) & (II), Worley 1963, Mansfield (1963(I)), Schmookler (1954) and others support the generalization that, at least beyond a certain level of size, the ratio of research and development expenditure to some index of size does not increase significently with size, and may not increase at all. This, however, must be qualified. Scherer (1965 (I)) found among the largest 500 corporations that the largest 100 accounted for a slightly smaller percentage of total research and development expenditure and patents than of total sales. Mansfield (1963 (I)) found that the largest firms measured in terms of sales in petroleum, drugs and glass spent a smaller percentage of their sales on research and development, than did "somewhat" smaller firms; that in chemicals the largest firms spent relatively more; and that in steel they spent relatively less although the computed difference was not statistically significant.

---

(1) It is to be noted that it is likely that an appreciable proportion of private research and development undertaken by small firms may be described as imitative and competitive and not innovative in the Schmpeterian sense.

Scherer's (1965 (I)) findings indicate that research and development employment inputs increased with size up to 500 million Dollar sales size and then tended to decline except in primary metals, while steel pulled back into a stage of increasing returns.

It may be noted that Worley's (1963) and Hamberg's (1964) results, because of differences in data and method, conflict with Mansfield's in the case of glass, petroleum, and chemicals, though they are reconcilable. Up to a certain size innovational effort increases more than proportional to size; at that size, which varies from industry to industry, the fitted curve has an inflection point and among the largest few firms innovational effort does not generally increase and may decline with size. For the three industry group both Hamberg and Mansfield fitted curves to all available observations and found research and development intensity to be an increasing function of size. Mansfield (1963 (I)) confined his analysis to the "very" largest firms. It is almost certain that Mansfield's petroleum and glass firms fell to the right of the inflection points of the curves fitted to a wider range of firm sizes.

A reconciliation of the findings reached by these studies brings out some interesting conclusions. Hamberg's (1964) conclusion is that gigantic scale is far from an essential condition for rigorous industrial research and development activity and that bigness may instead be a stifling factor. Scherer (1965 (II)), though , finding that Hamberg's conclusion is based on the "conventional standards" of significance, prefers some flexibility of the significance level especially in a situation of policy-making concerned with economic growth. Consequently he indicated his willingness to accept as "best estimate" that evidence which supports firm size, even though it passes the significance test only at .10, .20 or .30 levels.

Mansfield's (1964 (II)), in addition, found that contrary to the popular belief, the invention output per dollar of research and development expenditures seemed to be lower in the largest firms than in large and medium firms. His justification was that in part this might be due to looser control and greater problems of supervision in a very large organisation.

Moving to the population of small firms, i.e. those employing less than 500, the relationship between research and development employment and size, (as measured by total employment) does not show a steady consistency. A team at Nebraska University - Campel, McConnell and Preston (1964/65) found that the relative intensity of research and development seems to be negatively correlated with firm size. On the other hand, the frequency of research and development and the absolute number of employees engaged on research and development vary directly with firm size. The obvious conclusion is that while smaller firms within the under 500 employees classification are less likely to have research and development than larger ones, when they do have such programmes they are inclined to devote a larger percentage of their resources (as measured by employees on research and development) to them than do larger firms.

In spite of the extensiveness of investigating the relationship between size of the firm and its inventive-innovative activity in the United States, no similar application is known to have taken place in the United Kingdom. Unfortunately, the present study, because of lack of micro data, is in no position to undertake similar work for the United Kingdom.

(b) Determinate versus outcomes of technological innovation;

Productivity increase (Minasian, 1962), output growth (Kendrick 1961), and rapid growth rates and profitability (Mansfield, 1963 (I)), are regarded as the result of research and development expenditures and major individual innovations. Yet, it is equally likely that the causation may run from these factors to technological innovation. It may well be that growing firms and industries, (usually enjoying high productivity increase), can intensify their inventive-innovative effort which they can finance through production and profit expansion.

In view of the extremeness of the two lines of causation, it seems more likely that inventive-innovative efforts and production (and profit) expansion are probably inter-related,(1) (See Chapter X).

In the present application, the interest is directed towards evaluating the input of scientists and technologists, (i.e. the main components of inventive-innovative effort), to industrial production; rather than investigating the determinants of their effort.

(c) Total productivity;

Minasian's (1962) popular thesis, in line with Terleckyj (1958), and Kendrick (1961) advances the view that firms' research and development efforts are directed towards productivity increases. He proceeded to test the hypothesis that the greater the research and development experience the greater is the subsequent growth of the firm's (industry's) productivity. The sample with which Minasian dealt is 18 chemical firms and 5 drug and pharmaceutical firms. His conclusion is that beyond a

---

(1) The evidence built on high positive correlation between innovation and growth (and profitability) does not imply, statistically speaking, that causation run from one certain direction to another.

reasonable doubt, causality runs from research and development to productivity and finally profitability, though he does not ignore the monopoly power considerations.

Terleckyj (1963) summarises a pilot study he ran on Manufacturing Industries 1899 - 1953 in Colombia University 1960. He found that research and development personnel man hours was highly correlated with productivity changes. His conclusion is that research and development effort is aimed at expanding the range of technological possibilities, helping to ascertain the feasibility of prospective innovation, and planning the adoption of new technology.

Kendrick (1961) found a correlation between rates of change in total factor productivity, (meaning rates of change of output per unit of labour and capital only) and research and development expenditures. The correlation coefficient was 0.62.

(d) Growth of firms and industries;

The growth of firms and industries has been a favourable candidate to explain one of the fruits enjoyed by successful innovations. Mansfield (1963 (I)) compared the growth rates of a list of firms, that were first to introduce new processes and products which had emerged since the First World War, during the innovation period and before it. He found that the pay-off in terms of growth is quite considerable. Moreover, the comparison of innovators with other firms of equal size showed a marked difference between the two groups. In every time interval and for both industries, steel and petroleum, the successful innovators compared with the others enjoyed a rise in their rate of growth between 4 - 13 per cent, varying from one time interval to another and from industry to industry.

Freeman (1963) compared the performance of British and American industries. He found a high correlation between research and development expenditures and growth for a large number of industries. The growth indices are for the period 1935 - 1958, and research and development expenditures for 1958 seems to suggest that causality may run from growth to research and development. He concluded that the indirect evidence suggested that the pattern of research expenditure by industry has not changed greatly since 30 years ago.

Griliches (1964 (I)) used data on 68 agricultural regions in the United States over the years, 1949, 1954 and 1959 to estimate an aggregate agricultural production function. He introduced explicitly the level of public expenditure on agricultural research and development. This variable had a significant influence on the level of agricultural output. His conclusion is that public expenditure on research and development extensions is an important source of aggregate output, and appears to have a high social rate of return.

(e) Technological leadership and the speed of diffusion;

Case studies of individual innovations are an obvious choice as a means of investigating the fruits of gaining a technical lead. They are also useful in revealing the behaviour of those competitors who are concerned with imitating the leaders and in assessing the speed of diffusion. The contributors are many, among them are Freeman (1963), Mansfield (1962) (1963 (I))(II) & (III)); Muller (1957; Enos (1962); Jewkes (1958) and Moddala and Wright (1967). Only the work of the first two will be given brief consideration.

In his comparative study of research and innovations of the plastics industry, Freeman (1963) indicated that technological progress (presumably in the narrow sense), results in leadership in the production of plastics because patents and commercial secrecy together can give the innovator a head start of as much as 10 - 15 years. On a national level, other countries may shorten the catching up process if they are in a position to purchase the technical know-how or if they are countries in which innovators set up subsidiaries. He estimated a period of diffusion from the country of origin to other countries extending between 2 or 3 years for the most technically advanced country to more than 20 years for less advanced countries. However, even after patents expire, accumulated experience will help to keep the innovator in the lead. The importance of research and development projects to the plastics industry does not stop with the discovery of the raw material. It must be followed by intensive effort to:-

(i) explore new applications

(ii) achieve modifications

(iii) improve the quality of the products, and

(iv) decrease the cost of production.

Mansfield studied the factors responsible for the speed of response of firms to new techniques. The data he used relates to 14 major innovations. His findings indicate that the length of time a firm waits before using a new technique tends to be inversely related to its size. Though it was a common belief that other factors such as profitibility, growth rate, liquidity, profit trends, director age, were important, their efforts were shown to be in the "wrong" direction and were statistically non-significant. Time lag is not only involved in the process of catching up with technical leaders, but also between inventive-innovative effort and the commercial production. Scherer (II) adopted the assumption of a four years lag between the input of research and development personnel and patent application. Minasian's (1962) findings indicated a time-lag of between 2 and 4 years. Freeman (1963) estimated lag between research and development expenditures and normal commercial productions of between 5 and 12 years.

Micro data is essential for estimating the diffusion process, while macro data can be used for investigating the time lag or family of lags between inventive-innovativeeffort and industrial product. It is obvious that the latter is most relevant for application in the present study. This is because current industrial product is regarded as a function not only of current input factors, but also of those input factors allocated previously in order to improve future technology. The distinction between the various activities of scientific effort is based, among other things, on the allocation of scientific personnel between either current productive activities or in order to gain technological lead (see chapter X).

D. Production Functions in theory and practice.

The production function in theory is basically a microeconomic concept concerned with the alternatives open to the individual decision unit for the allocation of production resources. It is well known that in order to make the theory applicable some amount of aggregation is indispensable. Such an aggregation, however, brings among other things the problem of the correspondence between the production function in theory and in practice. "... aggregative relationships attract a certain interest of their own if only because the preponderant tradition in studies of production function has been to concentrate upon sector and whole economy levels".[1]

The inter-industry production functions have been widely applied more than once for many countries. In his survey article, Professor Walters (1963) provided a list of the authors who fitted inter-industry production functions, the countries concerned and the estimates arrived at.[2] In 1940

(1) Hildebrand and Ta-Chung Liu (1965) p.14.
(2) Walters (1963) p.36.

Douglas and Gunn fitted three inter-industry production functions for Victoria and another one for New South Wales. The same authors fitted in 1941 four inter-industry production functions for Australia. Douglas and Daly fitted four functions for Canada in 1943. Browne, in 1943, estimated two inter-industry production functions for South Africa. Marschak and Andrews (1944), estimated an inter-industry function for the United States of America. One function was estimated by Williams for New Zealand in 1945. In 1948 Douglas and others fitted five inter-industry functions for the United States. Lomax, in 1950, fitted two inter-industry production functions for the United Kingdom. Tewari (1954) Duth (1955) and Mutri and Sastry, 1957, respectively fitted three inter-industry functions for India.

The tendency to estimate inter-industry production functions has continued up to the present. Hildebrand and Ta-Chung Liu (1965) estimated an inter-industry production function for the United States industry in 1957. However, their main study is on inter-state production functins. Feldstein (1967) estimated inter-industry production functions for the United Kingdom. All industries in the United Kingdom including manufacturing industries were used in his estimation.

All types of macro and semi-macro production functions are subject to the aggregation bias in the conventional sense which results from adding up micro units where arithmetic sums and averages are available, instead of the theoretically desirable geometric ones, (Klein II, 1946). The present study is not an exception in this respect. However, the aggregation bias which this study is treating is that resulting from agglomeration of many types and qualities of production means and results in one figure. Another main source of aggregation bias is caused by ignoring the explicit representation of factors influential to productive activities which are likely to vary considerably from one industry to another. Because of the serious implication of ignoring these sources of bias from statistical and policy points of view, their detrimental effect should be reduced as far as possible. For this objective chapters V - XI are devoted.

In order to become economically meaningful inter-industry production functions should satisfy the following properties:-

1. Labour and capital must be fairly homogeneous across the industries. Since such a condition is almost impossible to achieve in practice, as an alternative the present study provides a distinction between various structures and qualities of labour and capital.

2. The level of activity must be almost adjusted for the prevailing phase of the trade cycle across industries. Since this is a testable hypothesis, it is appropriate to correct for the degree of capacity utilization. This is done also by the present study.

3. The technology and efficiency must be very close across industries. A satisfactory correction for differences in technology and efficiency would mean an elimination of almost all the residual from the estimated production function through the explicit introduction of almost all the components of technology and efficiency. This is difficult to achieve at the present stage of knowledge and data availability. In the present study the residual factor is largely reduced by the improvements referred to by (1) and (2) above, in addition the input of scientific effort, as representing an important component of technical efficiency, is explicitly introduced into the specification of the production function. Moreover, the input of management, as a major component in technical efficiency, is partly represented by the explicit introduction of scientific management in the specification of the production function.

It is a difficult task to attempt a clear cut distinction between the present study and the previous work, since the former is a continuation of the latter. However, it may not be far from realistic to draw the following comparison:-

1. The present study provides a direct measurement for two layers of vintage of capital and a direct comparison between the efficiency of modern and older vintages of all fixed assets. Solow (1959), constructed capital series

standardized for efficiency and predicted capital requirements. Hildebrand and Ta-Chung Liu (1965) were content to use net stock of capital instead of gross stock of capital in order to allow for the vintage of capital.

2. In the present study a distinction is established between plant and machinery and other structures of capital. Also a combined distinction for the structure and vintage of capital is drawn. Professor Wolfe and Brechling (1965) drew a distinction between investment in plant and machinery and investment in infra-structure capital.

3. The present study considers the degree of capacity utilization as affecting the technical efficiency of all factors of production rather than capital alone. In a cross-section of inter-industry study a correction for the level of activity introduced separately in the production function is called for by the lack of adjustment to the prevailing phase of the trade cycle. The precedence in the previous work calls mainly for correcting the stock of capital for the degree of capacity utilization, (see chapter VIII).

4. The present study advances and investigates the view that the input of scientists and technologists in industry should be treated as three separate functions viz. research and development, on-the-shop-floor and scientific management. As influential components of technology and efficiency, the input of scientists and technologists should be introduced explicitly in the specification of the production function. Ignoring scientific input is likely to result in biasing the estimated technical efficiency and the coefficients of the production function. If the scientific management input is accepted as partly representing the input of management, the indication here is favourable, then not only a proxy of management is suggested by this study but also a reduction in the managerial bias is likely to result from the explicit introduction of scientific management instead of relying on a catch-all dummy variable.

CHAPTER IV

DATA IMPLEMENTATION

In the literature , the input of research and development expenditures then personnel(qualified and supporting staff) is widely invistigated . As an input factor , research and development expenditures are used by Menasian (1962) , Mansfield (1965) and Griliches(1964) , and Brown and Conrad (1967)[1].

In the past there has not been adequate effort placed upon disaggregation of input variables such as scientific input. Indeed there has been relatively less effort to include scientific input on-the-shop-floor and scientific management in the production function. This is taken care of here. It is , however , advanced by Carter and Williams (1959) that a wide base of scientists and technologists is vital for the prosperity of research and development effort. The ratio of technical and professional to production workers was suggested by Hildebrand and Ta-Chung Liu (1965) as a proxy for technology and efficiency . Hoch (1962), Mundlak (1961) and Massell (1967) used the farm dummy as a proxy for management,(see pp.247-248).

5. The present study provides , among others , an estimation for the net stocks of all fixed assets , of plant and machinery , and other capital structures for 23 industries in Scotland in 1962. In the previous work Taylor (1967) used industrial electricity consumption to arrive at regional estimates for the stock of capital, yet gave one figure for Iron and Steel in Scotland , (see chapter IV).

---

1. Brown, M. and Conrad, A.H. :" The Influence of Research and Education on CES Production Relations" , in Conference on Research in Income and Wealth : Productin Relations NBER , N. Y. Columbia Press 1967 , pp. 341-394.

DATA IMPLEMENTATION

Introduction:

The need to incorporate this chapter in the analysis arose out of the considerations:-

1. More than one source of information has to be used over a number of periods. Thus the problems caused by variations in Standard Industrial Classification, sampling units, sampling technique, coverage and definition usually puts a strain on the comparability of the cross-section as well as time-series data;
2. Some of the data published by source of origin or already estimated by other bodies is so limited in its industrial breakdown that an effort to disaggregate such data is necessary to allow the empirical application of the main ideas of this study.
3. The discontinuity of such an important type of data as net output (the nearest to gross value-added concept), during the years 1959 - 1962 inclusive shows the need to interpolate Net Output for these years.
4. An attempt was felt necessary to estimate some of the needed, though unpublished data.

Had it been possible to acquire the data needed through a detailed questionnaire (as is usually hoped in similar investigations), then apart from constructing price indices, almost all other problems and means of coping with them, (i.e. the subject matter of this chapter), could have been largely avoided, or at least reduced to a minimum. Since it is necessary to deal with a number of data sources and a period covering 12 years, it is necessary to present in some detail the origin of the problems involved, their implications for the analysis, the method followed in minimizing their detrimental effect and the assumptions involved.

Not only does the basis of data collection vary from one source to another, but also the same source may be continually changing over time the basis on which it is publishing or collecting such data. For instance, the sampling unit may be firms, establishments, or individuals, the size in terms of employment of the units to be enumerated may vary from 11 and over, 25 and over, to 100 and over, and the industrial breakdown may be as detailed as a trade basis or as aggregated as an industrial order basis. Even if the basis of data collection remains the same for the same source the published details may change.

Data implementation often requires additional information from the same source, the use of supplementary sources, or the resort to statistical estimation. Resorting to the original source for additional information where this is possible raises the fewest problems. When it was felt that the required information might be there, requests were made for it to the bodies concerned. In some instances the additional data was given, in others it was not. The last resort is to employ statistical techniques in the process of data implementation. This was done where no other means of constructing suitable data was available, and where it was felt that the assumptions adopted were satisfactory or justifiable.

In this chapter the human factors, i.e. the Qualified Scientific Manpower and the numbers in employment will be dealt with first, then the measurement of the physical factors, i.e. net output, gross output, stocks of all fixed assets, of plant and machinery, and of new buildings and vehicles will be considered.

HUMAN FACTORS

A. Qualified Scientific Manpower:

The triennial Manpower surveys of Engineers, Technologists and Scientists are the main source of data. The first of these started in 1956.(1) This survey and the following two surveys relating to 1959 and 1962 will be regarded here.(2)

A number of major changes are made to the data published by the triennial surveys in order to preserve the temporal comparability of the data on Qualified Scientific Manpower.

It is important to note that although this study will proceed on the basis of cross-section data, the fact that an investigation into the existence of a time lag or a distributed lag between the input of research and development effort and the growth of industrial product indicates the necessity of observing comparability of the data on the employment of Qualified Scientific Manpower and in particular, those engaged in research and development for 1962, 1959 and 1956 surveys.

The major changes which took place in the published triennial surveys of Qualified Scientific Manpower are:-

(i) A change from the 1948 to the 1958 Standard Industrial Classification:

Although the first and the second triennial Scientific Manpower surveys were based on 1948 Standard Industrial Classification, only the 1956 survey needed transformation to the 1958 Standard Industrial Classification. The 1959 figures were rendered comparable to the 1962 on the basis of the 1958 Standard Industrial Classification in the third survey report. Thus the availability of 1959 survey data on both Standard Industrial Classifications gave the key to transforming the 1956 data to the 1958 Standard Industrial Classification.

---

(1) D.S.I.R. Report, 1956.
(2) H.M.S.O.: Comnd. 902, 1959; the Comnd 2146, 1963.

(ii) A change in the type of work breakdown:

A three-way breakdown of work is essential for distinguishing the main forms of scientific effort. Research and development personnel and on-the-shop-floor Qualified Scientific Manpower are the two main distinguishable types of work. The third which is equally essential is the Qualified Scientific Manpower engaged on managerial activities. The third division of Qualified Scientific Manpower provided by the first three triennial surveys incorporates in addition to managers, all other activities and thus distinguishes two of the three main forms of scientific effort.

(iii) A change in the definition of Qualified Scientific Manpower:

The definition of qualified scientists and technologists changed between 1956 and 1959 and between 1959 and 1962. The B.Sc. Technology, Higher National Diplomas, Higher National Certificates in fields other than Mechanical and Electrical Engineering and membership of three more professional institutions were enumerated by the 1959 survey but not by the 1956 one. No numerical adjustment is possible because of the lack of data. However, it was stated in the 1959 survey that " .... the number of persons omitted from the first enquiry on that account was small". The 1962 survey included more qualifications than the 1959 survey. It is fortunate that a distinction between the newly enumerated qualifications and the predecessors is provided by the former survey.

(iv) A change in the establishments coverage:

Although those establishments employing 11 - 99 employees were excluded from the first triennial survey of Qualified Scientific Manpower in Great Britain, the published data in the second and third surveys provide data for establishments employing 100 and over employees.

Comparability of data on Qualified Scientific Manpower with information published by either sources necessitates the availability of the data for small establishments. Unfortunately these are not available on an industrial breakdown basis for Qualified Scientific Manpower.

(v) A change in the industrial breakdown which calls for disaggregation:

To sum up; since the third triennial manpower survey provides an industrial breakdown and standard Industrial Classification comparable for the number of scientists and technologists employed in 1959 and 1962, then only the data provided by the 1956 survey needs to be similarly comparable. However, both the 1959 and the 1956 figures need to be adjusted in order to allow for the additional qualifications newly enumerated in the 1962 survey.

Since the corrections made for the data of 1956 are numerous they will be stated briefly. To arrive at figures of qualified Scientific Manpower for 1956 that are made comparable to those for 1962 requires the following steps:-

(a) A disaggregation of employed Qualified Scientific Manpower into finer breakdown for some industries in 1956.

(b) A transformation into 1958 Standard Industrial Classification which in turn requires:

(i) disaggregation of the employed Qualified Scientific Manpower into finer breakdown for some industries in the second triennial survey of 1959.

(ii) increasing the type of work breakdown given by the second triennial survey into three activities.

(iii) using the ratio of the Qualified Scientific Manpower in each activity on the basis of the

1958 Standard Industrial Classification for 1959 (as given by the 1962 Survey) to the number of Qualified Scientific Manpower on the basis of the 1948 Standard Industrial Classification of 1959 Survey to transform each activity in 1956 into the 1958 Standard Industrial Classification.

(c) An adjustment of the 1956 figures on the basis of the 1962 Survey in order to take into account the additional qualifications enumerated in 1962.

Table (4.1) provides in the first four columns the data published by the 1956 Survey apart from some disaggregation. The middle four columns allow a correction for the 1958 Standard Industrial Classification. The last four columns allow further for a correction for the qualifications newly enumerated by the 1962 survey.

In view of the fact that the correction for the newly enumerated qualifications is the least obvious among the corrections made, it will be dealt with in some detail; especially it affects both the first and the second manpower triennial surveys. The change in the definition of Qualified Scientific Manpower involved enumerating additional qualifications in the 1962 survey. Rubber, Plastic and Textile Technologists were added to Technologists, and Agriculture Scientists and Pharmacists were added to Scientists. It is thus obvious that the addition of these qualifications to the Qualified Scientific Manpower enumerated in 1962 will distort the temporal comparability of scientific effort for those industries which are the main employers of the stated qualifications while leaving unaffected the comparability of the number of qualified personnel between 1956 and 1959 and between the latter and 1962 in the remaining industries. For the sake of consistency of the analysis and in order to avoid the distortion the following attempt is made in order to achieve comparability of the number of Qualified Scientific Manpower employed for the three years.

The number of the newly enumerated qualifications as provided in the 1962 survey is divided between technologists and scientists. No type of work breakdown isprovided for the additional qualification, thus a separate correction is introduced for the number of technologists and for the number of scientists in each form of activity. For instance form (4.1) is used to correct the number of technologists employed in research and development activity in 1959 for the newly enumerated technologists in 1962.

$$R_{T\ 59} = \frac{A_{T\ 62}}{A^{*}_{T\ 62}} \cdot R^{*}_{T\ 59} \qquad (4.1)$$

where $R_{T\ 59}$ refers to the estimated number of technologists employed on research and development at 1959; $A_{T\ 62}$ stands for all technologists enumerated at 1962; $A^{*}_{T\ 62}$ represents the technologists employed in 1962, net of the newly enumerated; and $R^{*}_{T\ 59}$ refers to technologists employed on research and development in 1959 and enumerated according to the 1959 definition.

The same ratio $A_{T\ 62} / A^{*}_{T\ 62}$ was used to estimate the number of technologists employed on-the-shop-floor and on all other activities according to the 1962 definition.

A similar form was used to estimate the scientists employed in each one of three activities. For scientists employed in research and development.

$$R_{S\ 59} = \frac{A_{S\ 62}}{A^{*}_{S\ 62}} \cdot R^{*}_{S\ 59} \qquad (4.2)$$

Where the subscript S refers to the employed Scientists and all other notations are defined as before.

The estimated total number of scientists and technologists in a given activity, say research and development, is simply the sum of (4.1) and (4.2) i.e.

$$R_{59} = R_{T\ 59} + R_{S\ 59} \qquad (4.3)$$

As an example, the estimates of technologists in the cotton industry may be used to demonstrate the difference between the numbers enumerated and the adjusted figures for 1959.

	Research and Development	On-the Shop-Floor	Other including Management	Total
1. Enumerated Scientists	495	232	124	851
2. Enumerated Technologists	145	241	83	469
3. Estimated Technologists	307	480	168	955
Enumerated Total (1 + 2)	640	473	207	1,320
Assessed Total (1 + 3)	802	712	292	1,806

The two sets of enumerated and assessed figures for all industries are included in Tables (4.1) and (4.2) of the Appendix

Two assumptions are involved in the above estimates. The first assumption is that the additional qualifications are distributed proportionately on the three types of work. This is unavoidable in view of the lack of a breakdown of the newly enumerated qualifications in the 1962 Survey by type of work. The second assumption is that the situation of supply of the newly enumerated qualifications in 1959 is not appreciably different from 1962. It seems difficult to introduce further refinement on the assessed numbers which may regard the difference in the supply especially on an industry level. On a national level the supply situation must be taken into account. The ratio of the stock of active graduates (of the newly enumerated qualificatios), in the earlier year to their stock in 1962 may be used as the required factor of correction.

B. Qualified Scientific Manpower In Scotland:

Only the numbers employed in research and development are provided on a confidential basis and thus are not tabulated here.

C. Numbers in Employment:

The Ministry of Labour Gazette , the Digest of Scottish Statistics, Statistics on Income ,Prices , Employment and Productivity, and, the Annual Abstract of Statistics are the sources of data used to obtain figures on total employment , total insured labour , male employees , female employees , and unemployment.

The need to use temporal employment figures in estimating other variables called for changing the industrial classification for the years 1954 - 1958 inclusive from the 1948 to the 1958 Standard Inddusrial Classification. Trades were transferred to the appropriate classification and the ratios of 1959 labour on the basis of the 1958 Standard Industrial Classification to 1959 labour on the basis of the 1948 Standard Industrial Classification were used to correct for part trades . Both published and estimated employment figures for Gt. Britain are provided by tables (4.3)- (4.25) for each regarded industry over the period 1954-1963 inclusive .

The employment figures for the U.K. and Scotland are provided by table (4.28)

PHYSICAL FACTORS

D: Gross Output of the U.K.[1]

Problems of available industrial output data: the data which is theoretically desirable is in many cases difficult to obtain in practice, except perhaps via controlled experiments. For instance, for the measurement of industrial output, the concept of gross value added is widely accepted because it measures the contribution of each industry to the domestic product. In order that an industry may generate value-added it needs the input of labour which may be subdivided as men and women, adults and youths of various skills, scientific and managerial personnel. It also needs various forms of fixed and current assets; land and buildings, plant and machinery, vehicles, stocks of raw materials and finished products, work in progress and cash. Each one of these input factors has an ideal theoretical definition, but when it comes to existing data various degrees of approximation are involved.

Gross value-added is usually derived from total or gross output of each industry. The latter is the aggregate value of the goods made and other work done by the establishments within the industry. It is equal to the value of the industry's sales plus any increase (and minus any decrease) in the value of its stocks of finished, products, work in progress and materials. Output must be measured "free from duplication in the sense that the output of establishments sold to other establishments within the same industry group are excluded. Gross output free from duplication is independent of the structure and organization of the given industry and of the number of establishments in that industry for which returns are made. This definition of gross output does not correspond with that given by the Census of Production where the figures relate to all sales by establishments, including those to other establishments in the same industry. Moreover, the figures of gross output for each industry group include not only the value of the principle products of the industry group (i.e. the products typical of the industry), but also the secondary products and waste proceeds. Gross output is usually valued at factor cost. It is equal to the total sales valued at sellers' prices plus (or minus) stock appreciation.(1) Gross output includes goods made by the business covered by the return, those made for it by out-workers or by other firms from materials given out to them (sometimes described as goods made on commission) and waste products. It also includes any machinery or other items produced for use in the business covered by the returns. However, the value of any goods sold without being subjected to any manufacturing process (merchanted or factored) and canteen takings are as well included for 1963 and 1958 but not for 1954 - 1957 censuses.

Changing the sampling unit from establishment up to 1958 to business units henceforward brought about among other things a difference between the value of stocks at the end of 1958 and the beginning of 1959 and so reduced the comparability of gross output figures for the two years. Since no adjustment for such a difference is provided by the Census of Production, it seems that there are three ways through which differences between the estimated value of stocks at the end of 1958 and the beginning of 1959 can be brought about.

These are:-

(a) The figures for 1959 are wider in scope than the figures for

---

(1) The amount received by the seller is distinct from the amount paid by the purchaser. The difference represents transport, distribution and service charges paid by the purchaser and not included in the seller's price. Seller's price is on "ex works" basis, the purchaser's is on "delivered" basis.

1958 as they include stocks held by separate selling organizations and stocks held abroad, both of which are generally excluded by firms making returns on an establishment basis.

(b) The twelve months' period covered by firms" returns in the Census for 1958 does not in many cases end on 31st December, whereas the figures derived from the monthly and quarterly returns made for 1959 all relate to the calendar year.

(c) The stocks classified to one industry group in 1959 may have been spread over several industry groups in 1958.

Moreover, the change of the sampling unit from establishment to firm basis would distort the temporal comparability of gross output between the period pre and period post the change. This is because the output of an establishment used to be allocated to a given industry on the basis of its own principle product is after the change based on the principle product of the whole firm instead.

Apart from the change in the sampling unit and the resulting difference in stocks, separate differences between gross output of the main Census years and sample Census years. The differences may arise of two main considerations:-

(a) The proportion covered by the returns is considerably different.

(b) The returns are based on business years for main censuses while they are based on the calendar year for sample censuses.

It is on the basis of the above background that the gross output is published by the Board of Trade and consequently the net output is dirived.

Gross output figures are corrected for the change in the Standard Industrial Classification (See Section E below). Up to 1958 the figures of gross output used to be provided directly by the Census of Production. For the years 1959 - 1963 inclusive, sales and work done are corrected for changes in stocks and work in progress in order to calculate the figures of gross output which are given by tables (4.3 - 4.25).

E. Estimating Net Output for the U.K.

The net output of an industry represents the value added to materials by the process of production and includes for 1958 and 1963 the gross margin on any merchanted or factored goods sold. It is understood that there is no appreciable duplication in net output. It constitutes the funds from which wages, salaries, rents, rates and taxes, advertising and other selling expenses, and all other similar charges have to be met, as well as depreciation and profits. Net output was obtained by taking the total value of sales and work done; adding the value of stocks at the end of year, and deducting also the cost of materials and fuel purchased (including the value of goods purchased for merchanting and canteen supplies), amount paid for work given out to other firms and payment for transport. The net amount of duty paid was deducted and the net amount of subsidy received added.(1)

Net output figures are provided by the Board of Trade Census of Production on a yearly basis up to 1958. The provisional estimates of the main Census of Production 1963 provides one more observation on net output.(2) Net Output is regarded as essential from the point of view

---

(1) & (2) Board of Trade Journal, Dec. 24th 1965, pp. 1516 ff.

of the present analysis since it is the closest to the familiar value added concept. The former exceeds value added to the extent that it includes services bought from other industries. Value added measures among other things, the contribution of an industry to the domestic product. Therefore, one of the main data manipulation duties was to interpolate net output figures for the period 1959 - 1962 inclusive. Such relevant variables as gross output, labour, and time trends were used on their own or combined to form a predection function with the highest possible explanatory power for each one of the 23 industries. The range of $\bar{R}^2$ varied from 0.369 to 0.999. Different forms were suitable for different industries.[1]

However, in order to achieve the above-mentioned interpolation another difficulty had to be overcome. The time series used in interpolation goes back to 1954 containing a classification of industries according to the Standard Industrial Classification 1948 up to 1957 for gross output and net output and up to 1958 for labour. Thence the classification was changed to 1958 Standard Industrial Classification. After transferring Minimum List Headings to the relevant industries according to the 1958 Standard Industrial Classification a coefficient of correction was obtained from the Census of Production and the Ministry of Labour Gazette as follows:- The Census of Production 1958 re-estimated net output and gross output for 1954 on the basis of the 1958 Standard Industrial Classification while the information published in the 1954 Census of Production is based on the 1948 Standard Industrial Classification. Therefore, the ratio of the former to the latter was used to estimate net output and gross output for 1955 - 1957 inclusive on the basis of 1958 Standard Industrial Classification.

The Ministry of Labour Gazette provides employment figures for the year 1959 on the basis of the two Standard Industrial Classifications.

---

(1) See Appendix (4.11).

The ratios of employment on the basis of 1958 to 1948 Standard Industrial Classification were used to assess the total employment, the male employees and the female employees on the basis of 1958 Standard Industrial Classification for the period 1954 - 1958 inclusive. Published data and the results of the interpolation are summarised for each industry over the years 1954 - 1963 inclusive by tables (4.3) - (4.25) of the Appendix to this Chapter.

F. Disaggregating the Net Stock of All Fixed Assets of Plant and Machinery and of Vehicles and New Buildings for four industrial orders of the U.K.

The main sources used are:-

(a) The Board of Trade Census of Production for the years 1948, 1951 and 1954 - 1965 inclusive.

(b) Capital, Output and Employment 1948 - 1960. A Program for Growth. No. 4. Dept. of Applied Economics, Cambridge University.

(c) The follow up tables of capital provided directly by the Department of Applied Economics of the University of Cambridge.

(b) and (c) will be referred to below as the Cambridge figures.

The estimates of the stock of capital as provided by Cambridge falls short of the industrial breakdown aimed at by the present study. In particular, the Cambridge estimates augment under three groups of industry four Industrial Orders. For instance, the Mechanical Engineering, Scientific Instruments, Electrical Engineering and Electronics, which are treated as four industries here, are augmented under one industry called "Engineering and Electrical Goods" by Cambridge.

Also the Cambridge estimates treat all textile industries as one industrial group. They are disaggregated here into three industries, viz. Cotton, Flax, and Man-made Fibres, Wool Textiles, and Other Textiles.

Further, two industrial orders, viz. Clothing and Footwear and Leather and Leather Goods are augmented by Cambridge estimates under one industrial group called "Leather, Clothing and Footwear". They are regarded here as two separate industries.

Thus it was necessary to disaggregate the net stock of - all fixed assets, plant and machinery, new buildings, and vehicles for the pre-mentioned three industrial breakdown, into seven industrial breakdown.

In order to disaggregate the stock of capital and its structures given on the basis of broad industrial groups into finer breakdown two methods were carried out. Since the assumption involved by each is different, the main criteria of preferring one to the other is the performance of the disaggregated capital as an input factor in the estimated production function.

The first method involves the assumption that the ratio of the accumulated gross investment over the years 1948, 1951, 1954 - 1965 of a given individual industry to the total gross investment of the industrial group represents closely the ratio of its stock of capital (or structures) to the total stock of capital (or structures) of its industrial group. In other words, it is assumed that the relative accumulated gross investment over a certain recent period if a sub-industry is representative of the past experience of accumulating the relative stock of capital (or structures). The limitations of this approach are:-

1. It does not allow for the fact that the rates of growth (and consequently the rates of capital accumulating) of each sub-industry is different from other sub-industries within a given industrial group. For instance the rates of growth of Electronics and Electrical Engineering exceeds the rate of growth of Mechanical Engineering and Scientific Instruments. Also the Other Textiles is the expanding sub-industry of the Textiles group. On the premises that new capital is theoretically and empirically the most productive, this assumption may be regarded as an indirect way of giving more weight to the quality of capital. Fast growing sub-industries in the post-War period would be allocated

a proportion of the stock of capital of a given industrial group, on the basis of their post-war accumulated gross investment, probably greater than the actual proportion. The findings of Chapter IV indicate that the accumulated gross investment over the most recent seven years has the greatest contribution to the productive process means that this limitation becomes less important.

2. It means that the Stock of Capital at any time before 1965 is affected by the experience of capital accumulation of the future as well as that of the recent past. This limitation is only defensible on the grounds of considering a period of accumulating Gross Investment long enough to summarize the history of capital stock in order to be used in disaggregation.

The second method of disaggregation involved the alternative assumption that the experience of the most recent past accumulated gross investment of a given sub-industry in relation to the main industry is a reasonable approximation of its past experience of capital accumulation in relation to the main industry. Thus in disaggregating, e.g. the stock of capital for the main industry Engineering and Electrical Goods for 1962, the ratio of the accumulated gross investment for the sub-industry Mechanical Engineering over the years 1948, 1951 and 1954 - 1962 inclusive to the accumulated gross investment for the main industry over the same years, was used in estimating the stock of capital for the sub-industry for 1962.

This method of disaggregation avoids the limitation of relying upon future experience of gross investment accumulation. However, it is still subject to the first limitation and the concomitant qualification raised with respect to the first method. Since the estimates of the stock of capital which are disaggregated on the basis of the second method proved superior to the alternative estimates in the estimated production function, a decision was reached to prefer and, consequently, to use the estimates based on the second method.

The same technique was followed in disaggregating the stock of plant and machinery, the stock of buildings, and the stock of vehicles.

The estimates of the disaggregated stock of capital, and various structures over the years 1954-1963 inclusive are provided by tables 4.8 - 4.11 and 4.17 - 4.21 inclusive.

G. The Estimation of Gross Output and Net Output for Scottish Manufacturing Industries for 1962:

Apart from the main census years, there is no published data on gross output and net output for Scottish Manufacturing industries. Since both variables are needed as a measurement of industrial output, an attempt was made to arrive at these estimates.

The following sources were used:

(a) The 1958 Census of Production Summary Tables for Scottish Manufacturing Industries;

(b) The Digest of Scottish Statistics and, in particular, the following tables -

(i) the Index of Industrial Production

(ii) Petroleum Refining

(iii) Insured employees; Analysis by Industry

(iv) Unemployment

(c) Statistics on Income, Prices, Employment and Productivity;

(d) The Annual Abstract of Statistics.

Derivation of gross output and net output figures for Scottish manufacturing industries could have been simply achieved by accepting the ratio of Scottish output to the United Kingdom output in 1958 as valid in 1962. The prohibitive limitations of that assumption are that it implies that the growth experience and hence the structural changes, have been the same for Scottish manufacturing industries and British manufacturing industries over the period 1958-1962.

The ratio of employment for Scottish manufacturing industries to British manufacturing industries was not good either in arriving at gross and net output estimates because it involves the assumption that the labour productivity is the same for both sectors of manufacturing industries. In other words, such an assumption cannot be adopted in an inter-regional comparison, since it has to be one of the testable assumptions.

The alternative technique which is followed by the present study as being reasonable, involves the major assumption that changes of gross output and net output of Scottish manufacturing industries followed closely the movements of their physical counterpart, namely the Index of Industrial Production between 1958 and 1962.

Estimating net output and gross output for each one of the industrial orders involves first transforming the Index of Industrial Production for 1962 from 1954 = 100 to 1958 = 100 and, secondly, multiplying the 1958 gross output and net output by the estimated index for 1962. In other words gross and net output are estimated at 1958 prices.

The disaggregation of some of the above estimates of main industries to a finer industrial breakdown is necessary in order to achieve an industrial breakdown similar to that of British manufacturing industries. Two types of disaggregation was undertaken. The first type involved a limited number of sub-industries provided together with other sub-industries in the summary tables of the 1958 census of production for Scottish Manufacturing industries. In the second type of disaggregation 14 sub-industries are included in five industrial orders.

The two types of disaggregation and a step by step distrib-tion is provided by appendix III to this chapter.

H. Estimating the Stock of Capital for Scottish Manufacturing Industries:

It is generally agreed that data on capital stock is so scarce and difficult to compile especially on a fine industrial breakdown for the whole of the United Kingdom (see e.g. Nicholson 1966). The situation is even more difficult with respect to regional estimates. In an attempt to arrive at a regional estimate for the stock of plant and machinery on the basis of industrial electricity consumption, Taylor 1967, derived his estimates for five industry groups only, viz. Food, Drink and Tobacco, Chemicals, Allied Industries, Iron and Steel, Engineering and Other Metals, Paper, Printing and Publishing.(1) Even though as far as Scottish Manufacturing industries

(1) Taylor, 1967 summarises the logic of using industrial electricity consumption in estimating the stock of plant and machinery in "Industrial electricity consumption is complementary to the use of capital equipment because it is an important fuel input. Practically all mechanical power is now driven from electricity either supplied through the national grid system or generated privately on the firm's own premises .... The only significant area where electricity is used in large amounts for heat rather than for power is in the Steel Industry ..." p. 291.

is concerned only one figure was given as an estimation of the stock of plant and machinery in Iron and Steel; thus indicating the insufficiency of the data on industrial electricity consumption for filling the gap in regional data.

The attempt by the present study to estimate the stock of all fixed assets, the stock of plant and machinery, and the stock of other infrastructures must be viewed in the light of the lack of published data on the stock and the formation of capital. In spite of the attempts made to refine the method of estimation, the estimates arrived at must be regarded with caution. Although there is no direct way of telling whether or not they approximate closely to the actual stock of capital, the indirect method of judging the appropriateness of these estimates on the merits of their performance in the estimated production function is encouraging. Nevertheless, the fact that these are estimates and not original data must always be borne in mind in interpreting the obtained results.

Although more than one technique of estimation was considered only the one finally used will be described. The only relevant data which is published and possesses comparability for British and Scottish manufacturing industries is provided by the 1958 Census of production. It provides net output, the closest measure to value added, the wage bill, and profits. This data was used to arrive at estimates of the net stock of all fixed assets, plant and machinery, and other types of capital for Scotland as follows:-
Firstly: An intermediate production function was estimated for each of the British and Scottish manufacturing industries for 1958. The hypothetical nature of the intermediate production function is stressed since it is not meant to be a representative one but just a means of arriving at the Scottish manufacturing industries capital figures in 1962.

If it is assumed that the production function of each one of the British and Scottish manufacturing industries is linear and homogeneous, then for the i^{th} British industry it takes the form -

$$NO_{Bi} = \alpha L_{Bi} + \beta K_{AB_i} \quad \ldots \quad (4.4)$$

while for the counterpart industry in Scotland, it is

$$NO_{Si} = \alpha L_{Si} + \beta K_{AS_i} \quad \ldots \quad (4.4)'$$

where NO, L and K stands for net output, labour and capital, the subscripts B and S refer to British and Scottish manufacturing industries. The subscript A refers to all fixed assets. The homogeneity assumption implies that

$$\alpha + \beta = 1.$$

Using the 1958 data for both British and Scottish manufacturing industries, each may be estimated as the labour share in the value added or

$$\alpha_i = \frac{WB_i}{NO_i} \quad \ldots \quad (4.5)$$

Similarly β_i, the capital share, can be estimated as $(1 - \alpha_i)$, or as:

$$\beta_i = \frac{\text{Profit}}{NO_i} \quad \ldots \quad (4.6)$$

Secondly, assuming that the estimates of the α's and β's remain constant for 1962, and using in addition the labour and net output figures for 1962, we can estimate the stock of capital from:-

$$K_{ABi} = \frac{NO_{Bi} - \alpha_i L_{Bi}}{\beta_i} \quad \ldots \quad (4.7)$$

and

$$K_{ASi} = \frac{NO_{Si} - \alpha_i L_{Si}}{\beta_i} \quad \ldots \quad (4.7)'$$

where K_{ABi} and K_{ASi} refer to the intermediate estimate of the stock of capital in the i^{th} industry in the British and Scottish manufacturing industries respectively. Referring further to the Cambridge estimates of the stock of capital for British manufacturing industries as K^{*}_{ABi}, then estimates of the stock of capital for the i^{th} industry in Scotland as derived from the Cambridge estimate on the basis of the ratios of hypothetical estimates is:-

$$K^{*}_{ASi} = \frac{K_{ASi}}{K_{ABi}} \cdot K^{*}_{ABi} \qquad \ldots \qquad (4.8)$$

Thus, the intermediate estimates of capital were used just to provide a factor of proportionality to arrive at estimates of the net stock of all fixed assets for each manufacturing industry in Scotland.

As far as the estimation of the stocks of plant and machinery for Scottish manufacturing industries is concerned assimilar technique was followed. The stocks of all other types of assets were simply the difference between the stocks of all fixed assets and the stock of plant and machinery.

Table (4.32) gives the estimates of α_i's, B_i's, the ratios K_{ASi}/K_{ABi}, the stock of all fixed assets, of plant and machinery and of other infra structure capital for British and Scottish manufacturing industries.

APPENDIX I

Tables (4.1) and (4.2) provide mainly the number of qualified scientists and technologists employed in G.B. distributed by industry and type of work in 1956, 1959, and 1962. The last column of the two tables gives expenditures on research and development at current prices £m. in 1955/56 and 1961/62 respectively.

Tables (4.3)-(4.25) give for each one of the regarded 23 manufacturing industries over the period 1954-1963 the following published and estimated data:-

i) in the first three columns the total number "in thousand" of total employees, males and females in G.B. are provided. Employment data for the U.K. is given in Table (4.28).

ii) the fourth and fifth columns give the published and estimated current "£m's" gross and net output in the U.K.

iii) the columns 6-9 give mainly the Cambridge estimates of the net stocks of all fixed assets, plant and machinery, buildings, and vehicles in "£m.'s" at 1954 prices. Four Industrial Orders were treated as three industries by Cambridge estimates. These are disaggregated by the present study into nine industries (see section F).

iv) the columns 10-13 give net capital formation by type of asset at current "£m.'s".

v) the columns 14 and 15 give gross capital formation at current "£m.'s" for plant and machinery, and vehicles over the period 1956-1962 which are used in estimating modern stocks of capital. Published data does not distinguish between gross and net formation of buildings. The price indeces used in deflating capital formation are provided by Table (4.29).

It is important to regard that the estimated modern stock of capital is the sum of three separate estimates of the modern stocks of plant and machinery, building, and vehicles. The assumed life span of industrial buildings is 50 years and the assumed life span for vehicles is seven years for all regarded industries. The assumed life span for plant and machinery varies amongst industries. The assumed life span for each regarded industry is given by Table (4.27) which gives also the estimates of modern and older stocks of all assets , plant and machinery , and other capital structures as stipulated by chpters VI and VII.

(Table (4.1)

OCCUPATIONAL DISTRIBUTION OF SCIENTIFIC AND TECHNICAL MANPOWER IN

INDUSTRY	Numbers enumerated according to 1956 (1948 S.I.C.).			
	R & D_1	F_1	M_1	Total.
Food, Drink and Tobacco	426	1157	81	1664
Mineral Oil Ref.	461	719	123	1303
Other Chemical Industries	3935	3769	620	8324
Iron and Steel	483	1417	108	2008
Non-Ferous Metals	335	663	130	1128
Mechanical Engineering	2118	4680	779	7577
Scientific Instruments	496	188	77	761
Electrical Engineering	4302	2673	1094	8069
Electronics	2754	906	469	4129
Shipbuilding & Marine Eng.	69	617	89	775
Motor Vehicles	806	1165	141	2112
Aircraft	3359	851	49	4259
Other Vehicles	10	157	36	203
Other Metal Goods	295	1252	101	1648
Cotton, Flax and Manmade	540	411	58	1009
Wool Textiles	32	76	14	122
Other Textiles	187	594	15	786
Leather, Leather Goods	14	81	1	96
Clothing & Footwear	11	26	13	50
Bricks, Pottery, Glass, Cement	246	483	23	752
Timber, Furniture	39	76	2	142
Paper, Printing & Publishing	300	403	16	694
Other Manufacturing Industries	516	616	76	1208
TOTAL:	21724	22980	4115	48819

BRITISH MANUFACTURING INDUSTRIES, for 1956. (1948 & 1958 S.I.C.)

Numbers Estimated : 1956 Definition. (1958 S.I.C.)				Numbers estimated : 1962 definition (1958 S.I.C.)				Expenditures on R & D 1955/56
$R \& D_2$	F_2	M_2	Total.	$R \& D_3$	F_3	M_3	Total.	£000.
396	1143	85	1624	452	1305	98	1855	2.6
461	719	123	1303	462	720	123	1305	3.5
3915	3742	615	8272	3960	3929	1111	9000	20.0
482	1415	108	2005	484	1419	108	2011	3.2
419	718	141	1278	422	724	142	1288	1.6
1860	4600	770	7230	1871	4625	774	7270	15.1
464	270	110	844	465	271	110	846	1.8
2413	2527	1034	5974	2420	2534	1037	5991	19.4
3168	976	505	4649	3170	976	505	5651	14.0
69	604	88	761	69	605	88	762	0.2
536	969	117	1622	541	979	119	1639	3.6
4001	966	46	5013	4202	971	46	5219	84.2
10	147	34	191	10	148	34	192	0.1
338	1223	99	1660	341	1239	100	1680	2.2
555	417	59	1031	695	627	112	1434	3.6
32	74	14	120	124	234	125	483	0.2
186	687	12	885	254	1184	21	1459	1.1
14	81	1	96	14	81	1	96	0.1
11	26	13	50	16	45	13	74	0.1
192	507	24	723	193	509	24	726	1.8
27	67	2	96	30	76	2	108	0.2
203	356	14	573	212	372	15	599	1.9
441	540	67	1048	507	706	76	1289	2.8
20193	22774	4081	47048	20914	24279	4784	49977	183.2

OCCUPATIONAL DISTRIBUTION OF SCIENTIFIC AND TECHNICAL MANPOWER

INDUSTRY	R & $D_1 59$	$F_1 59$	$M_1 59$	Total.
Food, Drink and Tobacco	655	1218	286	2159
Mineral Oil Ref.	677	997	284	1958
Other Chemical Industries	5662	5040	1325	12027
Iron and Steel	639	1465	438	2542
Non-Ferous Metals	419	852	312	1583
Mechanical Engineering	2463	5606	2732	10801
Scientific Instruments	978	564	256	1798
Electrical Engineering	2625	2505	1425	6555
Electronics	3446	968	696	5110
Shipbuilding & Marine Eng.	246	608	366	1220
Motor Vehicles	491	1115	269	1875
Aircraft	3869	2522	477	6868
Other Vehicles	69	146	65	280
Other Metal Goods	293	881	330	1504
Cotton, Flax and Man-made	640	473	207	1320
Wool Textiles	18	91	27	136
Other Textiles	260	341	185	786
Leather, Leather Goods	20	40	18	78
Clothing & Footwear	16	34	16	66
Bricks, Pottery, Glass, Cement	268	548	195	1111
Timber, Furniture	19	63	11	93
Paper, Printing & Publishing	144	334	91	569
Other Manufacturing Industries	652	529	223	1404
TOTAL:	24669	26940	10234	61843

R & $D_i(t)$ Research and Development ($i = 1$ and 2),

$F_i(t)$ On the Shop Floor (i.e. Manufacture, Production operation, maintenance, Installation, and Design for Manufacture.

$M_i(t)$ All other work (including Management, Sales, etc.

IN BRITISH MANUFACTURING INDUSTRIES. (1958 S.I.C.). Table (4.2

R & $D_2$59	$F_2$59	$M_2$59	Total.	R & D 62	F.62	M.62	Total.	Expenditure on R & D 1961/62 £000.
849	1274	357	2480	981	1832	412	2775	7.1
678	998	284	1960	763	940	216	1919	6.0
5728	5293	2395	13516	6111	6686	2487	15725	39.7
641	1469	439	2579	938	2135	298	3771	5.5
422	859	315	1596	625	897	387	1877	4.5
2476	5636	2747	10859	2736	6493	3205	12434	24.9
980	566	257	1803	1108	423	318	1849	9.2
2633	2513	1429	6575	3676	3726	2221	9623	36.2
3449	967	697	5113	4685	1759	1040	7484	49.9
246	608	366	1220	247	737	442	1426	1.8
491	1125	272	1888	536	1107	292	1935	22.8
3889	2535	480	6904	4365	2336	914	7615	140.6
69	147	65	281	108	295	87	490	0.7
296	889	333	1518	600	1024	392	2016	7.0
802	712	392	1906	818	787	457	2062	5.6
70	288	241	599	44	183	149	376	0.4
355	588	323	1266	295	554	270	1109	2.0
20	40	18	78	14	111	11	136	0.2
29	59	16	94	28	74	29	131	0.6
269	550	196	1315	683	677	367	1727	4.3
21	71	12	104	47	96	23	166	1.0
150	349	95	594	464	594	213	1271	2.1
749	692	254	1695	775	772	329	1876	6.1
25312	28228	12423	65093	30647	33746	15400	79793	364.2

Subscript 1 represents number of scientists and Technologists enumerated by the 1959 survey according to 1956 definition amended at 1959 and rebased on 1958 S.I.C. by table(8) Pages 42 and 43 of the third triennial survey command 2146, 1963).

Subscript 2 gives the number of scientists & Technologists assessed by this study for 1959 according to 1962 definition, i.e. allowing for qualification but not enumerated, i.e. Agriculture Scientists, Pharmacy Graduates & Technologists in Rubber, plastics and textiles.

Table (4.3) FOOD, DRINK AND TOBACCO.

1948 S.I.C. (MLH 151-157, 162-164 and 168-169). 1958 S.I.C. (MLH 211-219, 229, 231, 239 & 240.)

						Net Stocks of Capital.				Capital Formation.				Gross K F	
	L_M	L_F	L_T	GO.	NO.	ALL	P & M	Bldg.	Vehs.	ALL	P & M	Bldg.	Vehs.	P &M	Vehs
S.I.C.1958															
54	424.2	329.0	753.2	3549.1	644.9	622.4	351.0	277.1	34.3	61.7	37.3	16.4	7.9		
55	427.4	342.3	769.5	3812.2	705.2	686.4	365.2	289.3	31.9	74.0	40.6	23.7	9.7		
56	430.0	347.9	777.8	3938.1	738.0	716.9	382.3	305.2	29.4	86.4	46.9	30.0	9.4	46.9	10.6
57	428.3	330.0	758.3	4097.5	759.3	747.5	401.3	321.2	25.0	94.0	53.1	32.4	8.6	53.1	10.2
58	440.4	338.4	785.5	4268.2	916.5	779.5	420.3	334.8	24.4	112.3	59.0	39.2	14.1	61.4	18.6
59	443.1	339.4	782.5	4281.3	961.1	808.7	437.4	346.6	24.7	106.0	56.9	35.4	13.7	58.8	19.2
60	444.5	342.8	787.3	4532.1	1029.7	848.1	461.1	361.1	25.9	128.1	67.2	44.0	16.8	69.9	23.9
61	452.6	350.1	802.7	4705.4	1098.3	891.8	486.5	378.2	27.1	140.2	74.3	48.9	17.0	77.3	24.1
62	459.2	353.9	813.1	4871.4	1166.9	933.0	512.6	393.9	26.5	142.3	76.3	50.8	15.1	79.0	21.8
63	457.2	337.4	794.6	4622.9	1248.2	978.7	540.0	410.3	28.4	145.0	79.5	50.5	15.0		
S.I.C.1948															
54	482.8	369.9	852.7	3234.7	594.5										
55	486.4	384.8	871.2	3474.5	650.1										
56	489.3	391.2	880.5	3589.2	680.3										
57	487.4	371.1	858.5	3734.5	700.0										
58	501.2	380.5	889.3												
59	503.1	380.5	883.6												

Table (4.4) <u>MINERAL OIL REFINING</u>

1948 S.I.C. (M.L.H.36). 1958 S.I.C. (MLH 262).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital. ALL	P & M	BLDG.	VEHS.	Capital Formation. ALL	P & M	BLDG.	VEHS.	Gross K F P &M	Vehs
S.I.C.1958															
54	30.3	6.5	36.8	304.8	37.0	172.1	129.4	42.7	..	15.7	12.9	2.8	0.1		
55	29.3	6.2	35.5	321.3	47.3	178.0	134.2	43.8	..	13.0	10.6	2.3	0.1		
56	31.5	7.0	38.5	346.1	49.6	189.3	142.4	46.9	..	21.9	17.3	4.3	0.3	17.3	0.3
57	31.9	7.1	38.9	384.1	43.0	216.4	163.5	52.9	..	42.0	34.2	7.5	0.3	34.2	0.3
58	33.2	7.1	40.2	383.0	35.1	238.3	182.5	56.8	..	39.5	32.1	7.2	0.3	32.2	0.4
59	33.5	7.3	40.8	403.6	49.1	248.4	189.8	58.6	..	23.4	19.8	3.4	0.2	20.1	0.2
60	32.7	7.2	39.9	481.4	57.3	250.2	189.8	60.4	..	15.3	11.3	3.9	0.3	11.5	0.3
61	32.5	6.8	39.3	499.7	58.8	256.2	195.1	61.1	..	23.6	18.8	4.4	0.4	18.8	0,4
62	26.0	5.4	31.4	537.5	62.6	257.8	196.0	61.8	..	17.2	14.5	2.5	0.3	14.5	0.3
63	26.9	4.1	31.0	500.5	63.9	254.7	193.2	61.5	..	26.8	23.0	3.5	0.3		
S.I.C.1948															
54	31.4	6.6	38.0	301.4	37.0										
55	30.3	6.3	36.6	318.0	47.3										
56	32.6	7.1	39.7	342.5	49.6										
57	33.0	7.2	40.2	382.0	43.0										
58	34.4	7.2	41.6												
59	34.7	7.4	42.1												

Table (4.5) OTHER CHEMICAL AND ALLIED INDUSTRIES.

1948. S.I.C. (MLH 30-35, and 39). 1958. S.I.C. (MLH 261,263,271-277).

	L_M	L_F	L_T	GO.	KO.	Net Stocks of Capital. ALL	P & M	BLDG.	VEHS.	Capital Formation. ALL	P & M.	BLDG.	VEH.	Gross K F P &M	Vehs.
S.I.C.1958															
54	310.5	133.4	443.9	1375.7	500.9	648.3	462.8	173.1	12.4	96.8	69.5	23.9	3.4		
55	324.8	137.2	462.0	1529.6	536.2	707.8	502.0	193.6	12.2	106.8	72.5	29.9	4.4		
56	328.5	140.1	468.6	1636.0	575.8	795.1	564.4	218.9	11.8	146.9	103.3	39.6	4.1	103.3	6.6
57	332.7	136.3	469.0	1733.9	624.9	885.6	631.1	243.2	11.[illegible]	149.9	109.5	36.6	3.8	109.5	6.3
58	340.3	136.0	476.3	1927.2	73[illegible].6	977.0	696.6	269.6	10.8	157.2	114.1	36.9	6.2	116.7	9.1
59	339.7	134.8	474.5	2131.4	742.6	1053.1	753.7	288.2	11.2	144.5	108.8	29.7	6.0	110.4	9.2
60	349.1	139.3	488.4	2270.1	794.0	1114.9	795.1	307.3	12.5	134.1	96.7	30.5	6.9	98.4	10.5
61	351.2	138.9	480.1	2283.3	845.4	1193.5	855.0	324.8	13.7	167.1	123.5	36.2	7.3	126.1	11.0
62	346.3	137.7	484.0	2339.7	896.8	1266.3	909.3	343.0	14.0	17[illegible].1	123.3	40.4	6.4	125.1	10.3
63	344.8	135.8	480.6	2180.2	952.1	1289.3	936.4	347.7	15.2	135.9	100.0	2[illegible].0	6.9		
S.I.C.1948															
54	322.1	138.7	460.8	1361.5	491.5										
55	336.9	142.7	479.6	1492.1	526.1										
56	340.8	145.7	486.5	1595.9	565.0										
57	345.1	141.8	486.9	1691.4	613.2										
58	353.0	141.4	494.4												
59	352.4	140.2	492.6												

Table (4.6) IRON AND STEEL.

1948 S.I.C. (MLH 40-44). 1958 S.I.C. (MLH 311-313).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	403.8	48.6	452.3	1272.4	416.2	509.8	377.6	128.1	4.1	69.6	58.0	10.4	1.5		
55	414.4	51.1	465.4	1465.3	485.8	545.9	406.6	135.5	3.8	70.0	56.6	12.0	1.4		
56	422.8	50.2	473.0	1797.5	514.5	589.3	439.1	145.8	4.4	85.3	67.1	16.5	1.7	67.1	2.0
57	426.2	48.5	474.6	1861.6	560.0	647.6	486.7	156.1	4.8	109.3	90.2	17.5	1.5	90.2	1.9
58	416.4	46.8	463.2	1723.0	549.7	710.7	540.0	165.6	5.1	128.5	108.5	18.2	1.8	109.5	2.3
59	397.9	45.1	443.0	1365.4	505.3	757.7	580.8	172.5	4.4	111.7	95.5	15.0	1.2	96.4	1.8
60	727.6	46.8	474.4	1713.1	623.0	844.0	650.0	189.3	4.7	167.1	138.0	27.1	2.0	139.1	2.7
61	439.8	47.9	487.7	1612.7	663.1	970.0	750.0	215.3	4.8	230.1	189.5	38.6	2.0	191.2	2.7
62	405.7	45.8	451.5	1458.8	640.4	1061.9	818.4	238.6	4.9	193.3	154.5	37.3	1.7	156.3	2.1
63	407.0	46.6	453.6	1812.1	626.8	1100.2	845.6	249.6	5.0	100.2	81.8	16.6	1.8		
S.I.C.1948															
54	395.8	46.3	442.1	1269.5	413.3										
55	406.2	48.7	454.9	1462.0	482.4										
56	414.4	47.9	462.3	1634.3	510.9										
57	417.7	46.2	463.9	1857.6	556.1										
58	408.1	44.6	452.7												
59	390.0	43.0	433.0												

Table (4.7) NON-FEROUS METALS.

1948 S.I.C. (MLH 49). 1958 S.I.C. (MLH 321-22).

						Net Stocks of Capital				Capital Formation.				Gross K F	
	L_M	L_F	L_T	GO.	NO.	ALL	P & M	BLDG.	VEHS.	ALL	P & M.	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958.															
54	97.8	25.0	124.7	520.6	116.3	109.4	64.7	42.4	2.3	11.1	8.0	2.7	.5		
55	105.5	26.9	132.3	630.3	146.6	116.7	69.4	44.9	2.4	13.8	9.0	4.1	.6		
56	108.1	26.9	134.8	673.7	166.0	128.3	76.7	49.3	2.3	21.3	13.6	6.9	.7	13.6	0.9
57	107.5	26.7	134.1	583.0	139.0	140.6	84.8	53.6	2.2	22.9	15.2	7.0	.6	15.3	0.9
58	104.4	25.7	130.1	565.0	139.5	144.2	87.3	54.8	2.1	15.0	11.0	3.4	.7	11.4	1.0
59	104.7	25.1	129.8	573.9	149.6	149.8	91.8	56.0	2.0	18.3	13.3	4.2	.8	13.6	1.1
60	114.0	28.0	142.0	678.2	180.7	157.0	97.9	57.2	1.9	21.6	15.9	4.7	1.0	16.4	1.4
61	116.6	28.1	144.7	646.0	175.9	165.7	104.7	59.3	1.7	23.4	16.7	5.7	.9	13.1	1.3
62	110.2	26.9	137.1	605.5	171.4	176.8	113.0	62.3	1.5	29.1	20.8	7.5	.8	21.5	1.1
63	111.2	26.4	137.6	675.2	198.9	182.6	117.0	64.3	1.3	24.5	18.1	5.5	1.0		
S.I.C.1948															
54	89.2	14.9	109.1	508.5	106.1										
55	94.3	21.4	115.7	615.6	133.7										
56	96.6	21.4	118.0	658.1	151.4										
57	96.1	21.3	117.4	569.4	126.8										
58	93.3	20.5	113.8												
59	93.6	20.0	113.6												

Table (4.8) MECHANICAL ENGINEERING

1948 S.I.C. (MLH 52 - 58 and 69). 1958 S.I.C. (MLH 331 - 339, 341, 342, and 349).

	L_M	L_F	L_T	G.O.	NO.	Net Stocks of Capital. ALL	P & M	BLDG.	VEHS.	Capital Formation. ALL	P & M	BLDG.	VEHS.	Gross K F P&M	Vehs
S.I.C.1958															
54	826.3	176.0	1000.3	1467.6	788.6	540.9	339.6	185.7	15.6	55.7	38.0	14.1	3.7		
55	852.5	192.0	1044.5	1612.8	828.1	576.8	361.1	201.0	14.7	71.2	46.6	19.7	4.9		
56	881.2	197.1	1078.3	1860.1	908.2	612.9	382.7	217.2	13.1	82.1	51.6	26.1	4.5	51.6	7.0
57	874.6	187.3	1061.9	1219.3	982.1	645.1	403.2	230.9	11.9	88.1	55.7	27.9	4.5	55.7	7.3
58	894.3	193.4	1087.6	2045.6	1015.0	664.4	413.5	240.5	10.4	87.9	55.5	26.9	5.	61.9	8.1
59	867.0	186.4	1053.4	2134.0	1082.1	709.8	428.6	250.8	10.4	77.5	49.1	22.8	5.5	52.1	8.7
60	911.5	200.4	1111.9	2526.0	1141.4	726.5	453.7	271.0	11.8	97.5	65.0	25.2	7.3	67.8	11.0
61	960.2	209.2	1169.4	2754.8	1200.7	757.9	472.4	273.3	12.2	115.2	72.8	34.7	7.6	76.5	11.0
62	971.6	212.4	1184.0	2718.4	1260.0	790.4	493.2	284.9	12.3	106.0	68.2	31.9	6.0	71.7	9.0
63	946.3	202.1	1148.4	2325.7	1317.5	823.1	514.6	295.0	13.5	101.0	70.0	23.5	7.5		
S.I.C.1948															
54	866.0	174.4	1040.4	1459.5	827.1										
55	893.5	190.2	1083.7	1604.4	868.5										
56	923.6	195.3	1118.9	1850.3	952.5										
57	916.7	135.6	1102.3	1909.2	1030.0										
58	937.3	191.6	1128.9												
59	908.7	184.7	1093.4												

Table (4.10) ELECTRICAL ENGINEERING

1948 S.I.C. (MLH 70, 71, 75 and 79) (1958 S.I.C. (MLH 361,362,365 and 369)

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C. 1958															
54	258.4	136.0	394.0	612.5	285.1	189.7	117.5	65.2	5.0	18.2	12.3	4.6	1.3		
55	273.4	149.6	422.4	724.0	310.9	200.0	124.8	70.6	4.6	26.2	17.3	7.1	1.8		
56	280.9	151.2	431.7	776.7	333.5	212.3	132.3	76.0	4.1	30.0	19.1	9.4	1.5	19.1	2.0
57	288.3	180.1	468.4	761.7	348.8	224.6	139.4	81.7	3.5	28.7	18.9	8.6	1.2	18.9	1.7
58	301.5	147.0	484.5	848.5	405.0	239.7	149.8	86.7	3.2	39.2	22.8	13.1	2.3	23.8	3.0
59	306.0	148.5	454.5	981.7	499.2	249.6	155.4	91.0	3.2	36.2	22.1	12.6	1.5	22.7	3.1
60	319.7	164.1	483.8	1063.9	549.8	262.9	164.4	94.9	3.6	41.6	27.0	11.9	2.7	27.7	3.7
61	330.2	168.8	499.0	1126.2	588.4	282.5	175.4	103.1	4.0	43.8	26.6	13.7	2.5	28.1	3.6
62	328.5	165.5	494.0	1140.9	595.4	294.6	183.1	107.4	4.1	39.0	26.0	10.8	2.2	27.8	3.2
63	327.2	165.4	492.6	1122.7	[illegible]	306.8	191.1	111.3	4.4	45.0	31.2	11.0	2.8		
S.I.C. 1948															
54	275.3	136.6	413.9	600.3	387.8										
55	291.3	152.5	443.8	709.3	313.8										
56	299.3	154.2	453.5	761.0	336.2										
57	307.2	148.4	455.6	746.3	352.1										
58	321.2	149.9	471.1												
59	326.0	151.4	477.4												

Table (4.9) SCIENTIFIC INSTRUMENTS

1948 S.I.C. (MLH 100 and 101). 1958. S.I.C. (MLH 351 and 352).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital. ALL	P & M.	BLDG.	VEHS.	Capital Formation. ALL	P & M	BLDG.	VEHS.	Gross K F P&M	Vehs
S.I.C.1958															
54	77.4	45.3	122.7	141.0	84.7	48.3	26.8	20.0	1.5	4.2	2.6	1.2	0.4		
55	80.6	48.0	128.6	153.2	90.3	51.6	28.5	21.7	1.4	6.7	3.9	2.4	0.5		
56	82.6	46.6	129.2	169.1	100.1	54.8	30.2	23.1	1.3	8.1	4.1	3.6	0.5	4.1	0.9
57	83.1	45.6	128.7	177.8	108.4	57.9	31.9	24.9	1.1	7.9	4.6	2.9	0.5	4.6	0.6
58	84.2	48.2	132.4	189.1	112.6	63.9	34.7	28.2	1.0	10.0	5.6	3.8	0.5	5.8	0.9
59	82.4	47.1	129.5	196.8	132.2	66.4	36.0	29.4	1.0	9.6	5.3	3.7	0.6	5.5	1.0
60	87.8	52.2	140.0	226.2	151.4	69.9	38.0	30.7	1.2	10.1	6.4	2.9	0.8	6.6	1.2
61	93.9	56.4	150.3	244.6	163.4	74.3	41.7	31.4	1.2	12.1	6.9	4.3	0.9	7.0	1.4
62	96.3	55.3	148.9	238.7	159.5	77.4	43.5	32.7	1.2	10.5	6.4	3.8	0.5	6.4	0.8
63	97.3	55.5	152.8	247.1	157.4	80.5	45.3	33.8	1.4	11.8	7.2	3.6	0.8		
S.I.C.1948															
54	63.8	38.8	102.6	110.5	65.4										
55	66.4	41.1	107.5	120.1	69.7										
56	68.1	39.9	108.0	132.5	77.3										
57	68.5	39.0	107.5	139.3	83.7										
58	69.4	41.2	110.6												
59	67.9	40.3	108.2												

Table (4.11) ELECTRONICS

1948 S.I.C. (MLH 72 - 74). 1958 S.I.C. (MLH 363, and 364).

						Net Stocks of Capital.				Capital Formation.				Gross K F	
	L_M	L_F	L_T	GO.	NO.	ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P& M	Vehs.
S.I.C.1958															
54	130.5	100.4	230.9	287.6	149.8	102.7	66.0	34.0	2.7	11.2	7.4	3.3	.5		
55	144.9	121.5	266.2	339.2	172.2	109.2	70.0	36.7	2.5	14.7	9.9	3.7	1.1		
56	142.7	109.6	252.3	382.9	195.3	116.6	74.6	39.8	2.2	19.2	12.6	5.7	.9	12.6	1.8
57	149.2	116.7	265.9	409.3	215.9	122.5	78.3	42.3	1.9	17.8	12.0	5.2	.6	12.0	1.2
58	153.3	113.5	266.8	423.7	210.0	134.8	87.7	45.5	1.6	18.9	12.4	5.7	.8	13.0	1.1
59	153.4	115.7	269.1	526.1	310.3	139.9	90.9	47.4	1.6	21.1	14.2	6.2	.7	14.5	1.4
60	163.0	130.0	293.0	57[illegible].3	336.8	147.5	96.2	49.5	1.8	25.4	17.0	6.7	1.7	17.3	2.3
61	171.5	129.5	301.0	620.5	365.1	163.7	105.7	55.8	2.2	26.4	16.8	8.1	1.5	17.5	2.1
62	185.5	143.5	329.0	630.1	373.6	170.6	110.4	58.1	2.2	23.4	16.4	5.6	1.4	17.3	2.0
63	189.3	147.0	316.3	681.8	382.1	213.7	115.1	60.2	2.4	27.8	18.2	7.8	1.8		
S.I.C.1948															
54	117.0	97.2	214.2	281.9	185.3										
55	129.7	117.6	247.3	332.5	213.0										
56	127.9	106.1	234.0	375.3	241.6										
57	133.7	113.0	244.7	401.2	267.0										
58	137.4	109.9	247.3												
59	137.5	112.0	249.5												

Table (4.12) SHIPBUILDING & MARINE ENGINEERING

1948 S.I.C. (MLH 50-51). 1958 S.I.C. (MLH 370).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital. ALL	P & M.	BLDG.	VEHS.	Capital Formation. ALL	P & M.	BLDG.	VEHS.	Gross K F P&M	Vehs
S.I.C.1958															
54	273.2	12.9	285.1	413.7	187.3	73.3	42.2	31.1	..	9.2	5.3	3.6	0.3		
55	276.1	12.9	289.0	441.1	202.2	79.4	45.4	34.0	..	9.6	5.3	3.9	0.4		
56	282.0	13.8	295.8	497.7	223.5	85.1	48.3	36.8	..	10.4	6.1	3.9	0.4	6.1	0.5
57	278.5	13.5	292.0	530.5	236.5	94.5	53.0	41.5	..	14.6	7.4	6.9	0.3	7.4	0.5
58	267.6	13.4	280.7	498.7	227.0	107.4	58.4	49.0	..	19.6	9.4	9.8	0.3	10.1	0.5
59	253.5	12.9	266.4	463.8	223.0	120.0	63.6	56.4	..	19.5	9.6	9.8	0.2	9.8	0.4
60	236.1	12.7	253.8	453.4	218.0	127.3	66.6	60.7	..	14.8	7.8	6.4	0.5	8.2	0.6
61	231.0	12.0	24.3	452.6	218.4	132.3	68.4	63.9	..	12.0	7.1	4.7	0.3	7.3	0.5
62	222.9	11.9	234.8	412.2	211.6	138.1	71.1	67.0	..	11.9	7.7	3.8	0.3	7.9	0.5
63	200.8	11.4	212.2	409.9	207.7	144.7	74.7	73.0	..	10.5	6.3	3.9	0.3		
S.I.C.1948															
54	272.2	13.1	285.3	417.0	178.6										
55	275.1	13.1	288.2	444.5	192.8										
56	281.0	14.1	295.1	501.0	213.1										
57	277.5	13.7	291.2	534.2	225.5										
58	266.6	12.6	280.2												
59	252.6	13.1	268.7												

Table (4.13) MOTOR VEHICLES

1948 S.I.C. (MLH 80). 1958 S.I.C. (MLH 381).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	305.5	57.6	363.1	879.5	308.9	260.0	188.2	48.4	3.4	22.4	17.8	3.8	0.9		
55	325.5	60.9	386.4	1079.4	359.3	283.1	201.2	78.7	3.2	45.8	30.9	13.7	1.2		
56	325.4	56.7	382.1	1036.9	323.0	312.9	220.1	89.8	3.0	58.3	40.9	16.3	1.0	40.9	2.0
57	299.1	50.1	349.2	1053.4	321.7	341.1	238.9	99.7	2.8	59.5	43.9	14.9	0.7	43.9	1.6
58	318.2	51.2	369.4	1344.2	410.5	353.2	243.1	107.4	2.7	44.0	29.4	13.3	1.3	30.8	1.7
59	329.8	52.0	381.8	1353.5	538.2	360.3	247.8	110.0	2.5	40.0	31.2	7.4	1.4	31.8	2.0
60	377.0	57.8	434.8	1620.7	636.9	379.4	254.8	121.3	3.3	55.4	35.7	17.4	2.3	37.2	3.2
61	357.7	54.8	412.5	1442.2	574.9	420.7	276.5	140.2	4.0	85.4	58.1	25.7	1.6	58.9	2.5
62	367.0	57.0	424.0	1482.0	591.7	554.4	293.0	156.8	4.6	77.7	52.3	23.9	1.5	53.0	2.5
63	388.9	58.9	447.8	1932.7	721.2	492.9	311.8	175.9	5.2	79.3	51.7	25.9	1.7		
S.I.C.1948															
54	283.8	45.6	309.4	884.8	364.8										
55	281.1	48.3	329.4	1043.2	424.3										
56	281.0	44.9	325.9	1086.0	381.4										
57	258.3	39.7	298.0	1059.8	379.9										
58	274.8	40.6	315.4												
59	284.8	41.2	326.0												

Table (4.14) AIRCRAFT

1948 S.I.C. (MLH 82). 1958 S.I.C. (MLH 383).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL.	P & M.	BLDG.	VEHS.	ALL	P & M.	BLDG.	VEHS.	P&M	Veh
S.I.C.1958															
54	230.3	41.9	272.2	392.9	205.9	177.2	106.4	67.3	3.5	11.7	7.4	3.7	0.5		
55	243.3	44.0	287.3	435.0	244.6	185.3	111.1	70.9	3.3	15.1	9.5	5.0	0.6		
56	259.6	48.0	307.6	527.0	276.8	190.9	116.3	71.5	3.1	20.9	13.4	6.4	1.1	13.4	1.2
57	262.1	47.7	309.8	570.8	288.5	194.2	119.2	72.1	2.9	19.4	13.5	5.4	0.5	13.5	0.6
58	253.3	44.7	298.0	580.4	284.8	194.1	119.8	72.6	1.7	17.9	9.2	8.3	0.4	9.9	0.6
59	242.9	42.0	284.9	573.8	286.0	193.9	119.2	74.1	0.6	20.9	7.9	12.7	0.4	8.6	0.8
60	242.9	42.0	284.9	56[illegible].9	298.4	194.4	120.2	73.6	0.6	17.3	11.2	5.2	0.9	11.7	1.2
61	252.1	45.0	297.1	586.1	324.0	194.4	121.9	72.1	0.4	16.5	12.9	3.[illegible]	0.6	13.5	0.8
62	243.0	42.0	285.0	623.6	323.3	194.3	122.2	71.6	0.5	17.6	11.2	6.[illegible]	0.3	12.8	0.5
63	255.7	38.2	263.9	6[illegible]2.1	322.2	191.8	120.3	71.1	0.4	15.5	9.0	6.[illegible]	0.2		
S.I.C.1948															
54	197.0	33.0	230.0	362.4	195.7										
55	208.1	34.7	242.8	4[illegible].9	232.5										
56	22.1	37.8	259.9	486.8	263.1										
57	224.2	37.6	281.8	526.4	274.2										
58	216.7	35.2	251.9												
59	2[illegible]7.8	33.1	240.9												

Table (4.15) <u>OTHER VEHICLES</u>

1948 S.I.C. (MLH 83, 85, 89). 1958 S.I.C. (MLH 382,384,385 & 389).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL.	P & M	BLDG.	VEHS.	ALL	P&M.	BLDG.	VEHS.	P&M	Vehs
S.I.C. 1958.															
54	190.5	22.5	213.0	274.6	120.6	79.5	41.4	38.1	..	4.6	3.3	1.1	0.3		
55	185.7	22.3	208.[illegible]	29[illegible].6	85.1	79.8	41.3	38.5	..	5.0	3.1	1.5	0.4		
56	183.6	22.0	205.6	3[illegible]9.4	90.5	81.1	42.2	38.9	..	6.2	4.2	1.5	0.6	4.2	0.7
57	185.2	22.1	207.3	327.8	96.9	84.3	44.0	40.3	..	8.9	5.7	2.5	0.7	5.7	0.9
58	181.0	21.9	203.[illegible]	324.9	123.[illegible]	86.4	44.8	41.6	..	7.9	5.0	2.6	0.3	5.5	0.4
59	171.4	21.7	193.1	267.1	118.7	88.4	45.6	41.9	0.9	7.5	5.0	2.2	0.4	5.3	0.6
60	168.8	23.2	192.0	287.7	127.8	86.6	44.4	42.2	0.8	6.2	3.5	2.4	0.3	3.8	0,5
61	160.3	20.7	181.0	283.6	126.0	84.7	42.2	42.5	0.7	7.2	4.4	2.5	0.4	4.7	0.6
62	145.1	17.9	163.0	254.8	143.2	87.2	44.0	41.8	1.4	5.7	4.1	1.2	0.3	4.3	0.5
63	136.3	18.8	155.1	197.6	100.8	82.1	41.9	40.2	1.1	3.2	1.2	1.8	0.2		
S.I.C.1948															
54	161.9	11.9	173.8	277.9	147.1										
55	157.9	11.8	169.7	289.5	103.8										
56	156.1	11.7	167.8	318.4	110.4										
57	157.4	11.7	189.1	340.4	118.2										
58	153.9	11.6	165.5												
59	145.7	11.5	157.2												

Table (4.16) <u>OTHER METAL GOODS</u>

1948 S.I.C. (MLH 90 - 95 and 99) 1958 S.I.C. (MLH 391 - 396 and 399).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital ALL	P & M	BLDG.	VEHS.	Capital Formation. ALL	P & M	BLDG.	VEHS.	Gross K F P&M	Vehs
S.I.C.1958															
54	304.2	184.9	489.1	883.7	258.0	240.7	144.6	87.9	8.2	22.6	14.9	5.5	2.2		
55	316.6	197.6	514.2	1051.4	295.7	253.3	151.2	93.6	8.5	29.1	18.2	8.2	2.7		
56	321.3	194.9	516.2	1126.2	310.6	267.3	161.3	97.2	8.8	34.4	23.0	8.5	3.0	23.2	4.2
57	315.7	181.7	497.4	1116.7	316.6	278.7	169.9	100.7	8.1	33.3	22.6	8.3	2.4	22.6	3.7
58	324.1	183.5	507.1	1180.0	439.3	287.9	175.2	104.1	8.6	30.3	18.7	8.8	2.8	19.9	4.4
59	325.5	179.5	505.0	1201.2	434.6	302.5	185.1	108.4	9.0	36.0	24.9	7.8	3.3	25.9	5.2
60	348.5	195.9	544.4	1386.0	483.4	319.4	197.4	111.6	10.4	41.7	28.9	9.0	3.8	29.8	5.9
61	361.4	169.4	557.8	1443.6	527.0	344.3	213.9	118.6	11.8	53.0	35.0	13.9	4.6	36.8	6.0
62	359.3	189.6	548.9	1453.7	560.8	362.5	225.8	123.5	13.2	45.6	30.1	11.7	3.8	31.2	5.8
63	360.9	185.6	546.5	1638.2	595.8	370.9	232.1	126.4	14.4	43.7	29.0	10.8	3.9		
S.I.C.1948															
54	310.1	178.8	488.9	874.5	337.0										
55	322.7	191.3	514.0	1040.8	386.2										
56	327.5	188.5	516.0	1114.8	405.7										
57	321.9	175.3	497.2	1098.6	413.6										
58	330.4	176.5	506.9												
59	331.8	173.0	504.8												

Table (4.17) <u>COTTON, FLAX, AND MAN-MADE FIBRES</u>

1948 S.I.C. (MLH 110, 111, 114, and 123 (part)).

1958 S.I.C. (MLH 412, 413 and 423).

	L_M	L_F	L_T	.GO.	NO.	Net Stocks of Capital. ALL	P & M	BLDG.	VEHS.	Capital Formation. ALL	P & M	BLDG.	VEHS.	Gross K F P&M	Vehs
S.I.C.1958															
54	181.9	264.4	446.1	850.2	256.6	320.4	193.0	124.5	2.9	19.8	15.8	3.3	0.7		
55	172.7	247.5	420.2	865.4	232.3	322.8	196.7	123.6	2.5	20.9	16.4	3.9	0.6		
56	165.5	233.9	399.4	829.0	232.9	322.0	197.9	122.0	2.1	20.3	15.9	3.8	0.6	15.9	0.9
57	162.5	230.4	392.9	865.3	248.9	321.1	199.2	120.1	1.8	19.2	15.8	2.7	0.7	15.8	1.0
58	159.5	213.2	372.7	665.6	225.8	297.7	184.5	111.7	1.5	14.0	11.2	2.3	0.5	12.5	1.1
59	149.6	190.1	339.7	616.6	210.5	294.1	182.7	109.9	1.5	16.6	11.4	4.4	0.9	13.8	1.4
60	143.9	179.1	323.0	667.1	231.0	294.3	183.7	108.8	1.8	20.6	16.1	3.4	1.1	18.0	1.7
61	140.1	174.0	314.1	655.2	232.2	286.0	183.2	100.8	2.0	25.5	21.3	3.1	1.0	23.2	1.7
62	129.4	150.6	280.0	596.7	219.0	287.1	185.6	99.5	2.0	23.9	19.8	3.4	0.7	21.3	1.4
63	129.7	142.8	272.5	535.1	235.0	288.0	188.6	98.1	1.9	22.8	19.3	2.6	0.9		
S.I.C.1948															
54	183.0	256.5	439.5	837.4	233.5										
55	173.7	240.1	413.8	768.5	211.4										
56	166.5	226.9	393.4	736.2	211.9										
57	163.5	223.5	387.0	768.4	226.5										
58	160.5	206.8	367.3												
59	150.5	184.4	344.9												

Table (4.18) WOOLIEN AND WORSTED

1948. S.I.C. (MLH 112) 1958 S.I.C. (MLH 414).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	95.0	118.8	213.8	600.8	145.5	136.9	71.0	63.4	2.5	7.6	5.2	1.8	0.6		
55	92.5	114.8	207.3	575.2	156.2	137.6	72.1	63.4	2.1	8.7	6.2	1.9	0.5		
56	91.5	116.6	208.1	559.3	156.9	135.0	72.4	62.6	1.8	9.1	5.6	2.9	0.6	5.6	1.0
57	92.9	116.8	209.7	604.5	154.7	137.4	73.0	61.9	1.5	11.3	7.9	2.8	0.6	7.9	1.1
58	91.0	107.7	198.7	522.6	136.7	139.3	75.7	62.3	1.3	8.2	5.8	1.8	0.6	6.1	1.0
59	91.0	106.0	197.0	560.4	152.8	137.6	75.1	61.3	1.3	9.0	6.3	1.9	0.7	6.6	1.3
60	91.3	108.5	199.8	566.4	165.8	137.7	75.5	60.7	1.5	11.1	7.8	2.3	1.0	8.3	1.6
61	92.4	107.5	199.9	560.6	173.5	138.5	77.2	59.6	1.7	12.4	8.7	2.9	0.8	9.4	1.3
62	88.0	99.0	187.0	533.8	173.5	138.0	78.1	58.2	1.7	11.9	8.7	2.6	0.6	9.2	1.0
63	88.9	99.9	188.8	577.5	186.1	139.0	79.4	58.0	1.6	11.9	9.2	1.9	0.8		
S.I.C.1948															
54	93.2	119.2	212.4	596.5	144.4										
55	90.8	115.2	206.0	571.4	155.0										
56	89.8	117.0	206.8	555.7	155.7										
57	91.2	117.2	208.4	600.8	153.5										
58	89.3	103.1	197.4												
59	89.3	106.4	195.7												

Table (4.19) <u>OTHER TEXTILES</u>

1948 S.I.C. (MLH 113, 115 - 121, and 129)

1958 S.I.C. (MLH 411, 415 - 419, 421, 422 and 429).

						Net Stocks of Capital.				Capital Formation.				Gross K F	
	L_M	L_F	L_T	GO.	NO.	ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	137.0	184.5	331.5	619.7	237.9	390.9	216.3	169.9	4.7	27.5	20.5	5.9	1.0		
55	138.4	190.9	329.3	639.4	247.2	393.7	220.5	169.2	4.0	33.3	24.0	8.0	1.3		
56	137.2	188.1	325.3	644.5	250.9	406.8	236.4	167.1	3.3	27.9	21.2	5.6	1.1	21.2	1.8
57	137.0	184.1	321.1	648.4	257.4	391.3	223.4	165.2	2.7	29.8	22.8	6.1	0.9	22.8	1.7
58	132.2	173.2	305.5	654.1	252.8	415.0	244.7	168.0	2.3	29.9	21.9	6.6	1.3	23.9	2.2
59	132.1	170.9	303.0	730.9	311.5	410.0	242.3	165.3	2.4	27.9	20.7	5.6	1.5	21.8	2.5
60	139.6	177.8	317.4	834.4	372.1	410.3	243.7	163.8	2.8	36.6	25.8	8.8	2.0	26.9	3.2
61	142.8	178.5	321.3	855.3	384.4	432.0	257.1	171.6	3.3	47.5	35.0	10.7	1.8	36.4	3.1
62	142.6	178.4	321.0	839.8	375.2	433.2	260.5	169.5	3.2	38.1	28.3	8.3	1.5	30.4	2.6
63	144.9	174.6	319.5	869.6	391.7	434.6	264.7	166.9	3.0	36.1	27.1	7.2	1.8		
S.I.C.1948															
54	137.1	199.7	336.8	605.8	261.4										
55	138.5	196.1	334.6	625.1	271.6										
56	137.3	193.2	330.5	630.0	275.7										
57	137.1	189.1	326.2	633.8	282.8										
58	132.3	177.9	310.2												
59	132.2	175.5	307.7												

Table (4.20) LEATHER, LEATHER GOODS AND FUR

1948 S.I.C. (MLH 130 - 132). 1958 S.I.C. (MLH 431 - 433).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	42.0	30.2	72.2	152.3	44.8	30.3	13.2	15.5	1.6	2.0	1.1	0.6	0.3		
55	41.3	31.0	72.3	147.9	44.6	30.5	13.3	15.7	1.5	1.9	1.1	0.4	0.3		
56	39.0	28.9	67.9	142.3	46.5	30.5	13.3	15.8	1.4	1.7	0.9	0.6	0.3	0.9	0.5
57	33.5	27.8	61.3	149.8	45.9	30.0	13.3	15.3	1.4	1.9	1.1	0.5	0.3	1.1	0.5
58	36.7	26.2	62.9	136.6	43.3	28.4	12.7	14.4	1.3	1.8	1.1	0.3	0.3	1.0	0.5
59	36.4	26.4	62.8	186.6	60.1	28.4	12.7	14.2	1.5	2.2	1.2	0.6	0.4	1.4	0.7
60	36.4	26.5	62.9	184.1	60.5	28.8	13.2	13.9	1.7	2.8	1.5	0.9	0.5	1.6	0.7
61	36.1	26.6	62.7	184.5	61.6	27.8	13.1	12.8	1.9	3.2	1.9	0.9	0.5	2.0	0.7
62	35.9	26.1	62.0	176.5	60.4	28.4	13.5	13.1	1.8	2.8	1.8	0.7	0.4	1.9	0.6
63	35.5	24.4	61.9	166.1	58.6	29.6	13.6	12.9	2.1	2.7	1.4	0.7	0.5		
S.I.C.1948															
54	42.7	29.8	72.5	151.3	43.7										
55	42.0	30.5	72.5	147.0	43.5										
56	39.7	28.5	68.2	141.6	45.4										
57	34.1	27.4	61.5	148.9	44.8										
58	37.3	25.8	63.1												
59	37.0	26.0	63.0												

Table (4.21) CLOTHING AND FOOTWEAR

1948 S.I.C. (MLH 140 - 143, and 147 - 149).
1958 S.I.C. (MLH 441 - 446, 449 and 450).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL.	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	162.3	435.5	597.8	706.3	279.0	126.8	52.8	67.3	6.7	8.2	4.3	2.4	1.5		
55	158.9	426.3	585.2	712.0	279.3	128.3	53.9	67.8	6.4	9.1	4.6	2.7	1.8		
56	156.0	431.6	587.3	735.7	294.6	128.5	54.0	68.4	6.1	9.9	4.9	3.5	1.6	4.9	2.4
57	157.1	423.8	580.9	752.6	309.9	129.5	55.1	68.6	5.8	9.1	4.9	2.8	1.5	4.9	2.9
58	149.8	407.7	552.4	747.0	308.3	127.7	53.8	68.2	5.7	9.5	5.2	2.7	1.7	5.5	3.0
59	148.0	398.0	546.0	779.9	339.5	127.2	53.8	67.1	6.3	10.8	6.1	2.8	1.5	6.5	3.4
60	151.3	413.9	565.2	896.0	405.1	129.2	55.2	67.1	6.9	14.7	7.8	4.3	2.0	8.1	4.2
61	154.3	414.8	519.1	924.1	424.8	134.5	57.1	69.9	7.5	16.8	8.5	6.2	1.8	8.8	3.6
62	152.0	409.0	561.0	885.6	409.5	137.1	58.4	71.2	7.5	16.4	8.0	6.9	1.5	7.4	3.1
63	146.5	403.2	549.7	855.2	400.6	137.3	58.9	70.1	8.3	13.0	6.9	4.0	1.8		
S.I.C.1948															
54	185.1	460.8	645.9	700.6	268.6										
55	181.3	451.0	632.3	706.6	268.9										
56	177.9	456.6	634.5	729.9	283.6										
57	179.2	448.4	627.6	747.7	298.3										
58	170.8	431.4	602.6												
59	168.8	421.1	589.9												

Table (4.22) BRICKS, POTTERY, GL SS, CEMENT, ETC.

1948 S.I.C. (MLH 20 - 24 and 29) 1958 S.I.C. (MLH 461 - 464 and 469).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BIDG.	VEHS.	ALL	P & M	BIDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	255.7	83.5	339.2	493.9	251.8	190.6	105.9	76.2	8.5	25.2	16.7	6.1	2.3		
55	258.1	87.1	345.2	535.9	268.1	204.1	116.5	79.7	7.9	26.9	17.1	7.2	2.6		
56	259.4	85.5	345.0	575.3	283.7	221.3	128.4	84.6	8.3	32.6	21.1	8.7	2.8	21.1	3.6
57	252.8	80.9	334.0	598.2	295.8	241.4	142.7	90.1	8.6	33.0	21.6	8.6	2.7	21.6	3.6
58	247.4	77.9	325.3	594.9	296.6	245.7	150.5	95.2	9.0	32.9	20.4	9.2	3.3	21.0	4.3
59	246.4	76.0	322.4	603.4	317.7	268.2	158.7	99.2	10.3	30.1	18.1	7.9	4.1	18.6	5.3
60	256.4	78.8	335.2	692.7	355.1	292.1	174.1	106.0	12.3	42.9	26.6	11.3	4.9	27.2	6.4
61	262.5	80.8	343.3	728.8	386.7	323.0	192.5	115.6	14.9	54.3	32.6	13.3	5.5	33.6	6.9
62	265.9	81.0	346.9	744.9	441.7	354.1	213.8	124.0	16.3	58.7	37.6	16.3	4.8	38.0	6.1
63	260.1	77.2	337.3	758.6	421.4	377.7	226.3	132.2	19.2	50.1	31.9	11.1	7.1		
S.I.C.1948															
54	255.1	82.3	337.4	700.6	243.6										
55	257.5	85.8	343.3	706.6	259.4										
56	258.8	84.3	343.1	729.9	274.5										
57	252.2	79.7	331.9	747.7	286.2										
58	246.8	76.8	323.6												
59	245.8	74.9	320.7												

Table (4.23) TIMBER, FURNITURE, ETC

1948 S.I.C. (MLH 170 - 173 and 179) 1958 S.I.C. (MLH 471 - 475 and 479)

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs.
S.I.C.1958															
54	232.9	58.2	291.0	451.6	184.9	99.2	43.0	46.2	10.0	10.8	4.9	3.4	2.6		
55	235.5	60.5	296.2	466.0	188.0	104.6	45.2	49.4	10.0	12.7	5.4	4.5	2.8		
56	226.4	59.5	285.9	474.3	196.6	108.3	47.3	51.6	9.4	10.3	4.5	3.7	2.2	4.7	3.1
57	220.2	58.2	278.4	503.6	207.1	109.8	47.3	53.7	8.8	10.8	4.3	4.1	2.4	4.6	3.6
58	220.4	57.7	278.0	509.1	211.9	112.2	48.2	54.8	9.2	10.0	4.2	3.2	2.5	4.7	3.7
59	221.6	57.8	279.4	583.5	226.4	119.4	52.0	56.9	10.5	14.2	6.3	4.3	3.6	7.0	5.0
60	229.1	59.4	288.5	662.1	240.4	128.3	55.6	59.9	12.8	17.0	6.4	6.3	4.3	7.0	6.1
61	227.7	59.4	287.1	648.9	244.8	134.0	58.0	62.8	13.2	14.9	5.9	5.8	3.3	6.4	4.8
62	227.1	57.8	284.9	606.6	246.1	138.6	59.3	65.7	13.6	13.9	5.5	5.7	2.8	5.9	4.0
63	225.6	55.7	281.3	644.1	275.9	143.8	60.5	68.5	14.8	19.6	8.8	6.6	4.2		
S.I.C.1948															
54	234.2	60.9	295.1	446.6	243.6										
55	236.8	63.5	300.3	461.0	259.4										
56	227.6	62.3	289.9	469.2	274.5										
57	221.4	60.9	282.3	498.4	286.2										
58	221.5	60.4	281.9												
59	222.8	60.5	283.3												

(Table (4.24) PAPER, PRINTING, AND PUBLISHING.

1948 S.I.C. (MLH 180-183, 186 and 189). 1958 S.I.C. (MLH 481,482- 486 and 489).

						Net Stocks of Capital.				Capital Formation.				Gross K F	
	L_M	L_F	L_T	GO.	NO.	ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	327.7	192.8	520.5	953.8	445.5	391.5	253.1	133.5	4.9	36.3	25.0	8.9	2.4		
55	341.3	200.5	541.6	1041.4	484.1	410.7	262.8	140.2	7.7	44.4	29.5	12.2	2.7		
56	348.7	204.9	553.4	1088.8	497.9	438.8	278.7	152.7	7.4	61.3	39.3	19.7	2.5	43.0	3.7
57	357.0	200.3	557.3	1160.0	528.3	469.7	248.1	163.9	7.1	68.7	46.5	19.7	2.4	51.0	4.1
58	362.8	203.0	565.8	1252.5	577.0	491.7	313.0	170.9	7.8	65.3	44.2	17.8	3.1	45.6	5.1
59	368.2	200.5	568.7	1288.7	636.3	509.9	323.7	177.7	8.5	60.0	40.8	15.9	3.5	41.9	5.6
60	387.2	209.8	597.0	1508.7	771.1	532.9	336.7	185.3	10.9	67.9	45.0	18.1	4.9	47.7	7.4
61	397.2	215.3	612.5	1543.9	792.7	558.9	352.9	192.8	13.2	76.7	52.2	20.1	4.4	54.3	6.9
62	403.4	218.0	621.4	1534.9	78[illegible].0	583.2	366.4	202.5	14.3	78.8	51.0	23.5	4.1	52.3	6.8
63	408.3	213.1	621.4	1635.2	856.8	606.9	383.7	207.9	15.3	55.7	53.1	21.6	5.0		
S.I.C.1948															
54	336.1	194.1	530.2	939.3	448.6										
55	350.0	201.9	551.9	1026.3	487.5										
56	357.6	206.3	563.9	1073.6	501.4										
57	366.1	201.7	567.8	1144.8	532.0										
58	372.1	204.4	576.5												
59	377.6	201.9	579.5												

Table (4.25)
OTHER MANUFACTURING INDUSTRIES

1948 S.I.C. (MLH 190 - 195 and 199). 1958 S.I.C. (MLH 491 - 496 and 499).

	L_M	L_F	L_T	GO.	NO.	Net Stocks of Capital.				Capital Formation.				Gross K F	
						ALL	P & M	BLDG.	VEHS.	ALL	P & M	BLDG.	VEHS.	P&M	Vehs
S.I.C.1958															
54	150.7	115.0	265.4	441.5	183.8	141.1	93.0	44.8	3.3	15.3	11.4	2.8	1.1		
55	159.2	119.4	278.4	498.1	198.1	153.4	102.3	48.0	3.1	22.0	15.6	5.1	1.3		
56	161.3	116.3	277.9	521.0	200.4	167.7	112.9	51.1	3.7	25.1	18.5	5.6	1.0	18.5	1.4
57	158.6	111.3	270.0	536.3	219.8	180.9	121.4	56.1	3.4	25.6	18.3	6.3	1.0	18.3	1.5
58	165.6	112.4	277.9	541.6	227.4	192.8	129.8	59.1	3.9	22.2	16.0	4.9	1.3	16.6	2.3
59	167.7	110.1	277.8	594.6	262.1	206.4	140.3	62.0	4.1	24.1	18.0	4.6	1.6	19.0	2.6
60	179.7	120.6	300.3	697.1	318.9	224.7	152.8	67.8	4.1	31.0	21.5	7.4	2.2	22.3	3.2
61	181.5	123.0	304.0	695.7	318.2	42.1	166.6	71.4	4.1	33.0	23.9	7.1	2.0	24.5	3.2
62	184.0	120.3	304.3	708.1	325.0	259.7	180.9	74.6	4.2	34.5	25.4	7.3	1.7	26.0	2.8
63	187.6	120.1	307.7	762.8	357.3	274.0	192.1	77.6	4.3	38.1	26.9	8.7	2.5		
S.I.C.1948															
54	155.7	116.3	272.0	430.9	177.8										
55	164.5	120.8	285.3	487.3	191.6										
56	166.7	117.7	284.8	508.9	193.9										
57	163.9	112.6	276.5												
58	171.1	113.7	284.8												
59	173.3	111.4	284.9												

APPENDIX II

Table (4.26) The Production functions and the value

Industry	Constant Term.	Gross Output Coef.	Actual in 1962
Food, Drink & Tobacco	549·5		
Mineral Oil	8·599	0·1005 (0·0500)	537·5
Other Chemicals	434·2		
Iron & Steel	-968·39		
Non Ferous Metals	-24·4	0.2563 (0·0295)	605·5
Mechanical Engin.	726·0		
Scientific Inst.	3·802	0·6524 (0·2980)	238·7
Electric Eng. & Electronics	-164·87	0·6403	1771·0
Electric Eng. (a) Intermediate	234·0		
(b) Adjusted			
Electronics (a) Intermediate	114·9		
(b) Adjusted			
Ship Build. & Marin. Eng.	36·189	0·2507 (0·0307)	412·2
Motor Vehicles	35·717	0·3607 (0·0154)	1482·0
Aircraft	-116·01		
Other Metal Goods	36·6		
Cotton, Flax, etc.	-9·78	0·3096 (0·0551)	596·7
Wool	98·5		
Other Textiles	-116·6	0·5857 (0·0090)	839·8
Leather	1·087	0·283 (0·078)	
Clothing	-98·1	0·5228 (0·1282)	585·6
Bricks, Pottery etc.	-266·2		
Timber, Furniture, etc.	130·9	0·1043 (0·0177)	606·6
Paper, Printing etc.	-153·4	0·6128	1534·6
Other Manu. Ind.	-67·4	0·5542 (0·0410)	708·1

*These are the predicted net output for Electric Eng. and Electronics as obtained from their individual functions separately. However, both values are adjusted to the value of net output obtained for the total.

predicted for Net Output of the U.K. industries in 1962.

Labour Coef.	Labour Actual in 1962	Form. of Plant and machinery Coef.	Form. of Plant and machinery Actual in 1962	Time 1962-9 coef;	Projected net output for 1962	$\overline{R}^2$
				68·6 (5·6)	1166·9	0·968
					62·6	0·369
				51·40 (1·88)	896·8	0·993
3·015 (0·457)	463·2			23·010 (1·346)	640·4	0·983
				4·4685 (0·6339)	171·4	0·981
				59·342 (1·878)	126·0	0·995
					159·5	0·432
					969·0	0·990
				34·89 (2·29)	548·0*	0·979
					595·4	
				25·43 (2·569)	343·8*	0·951
					373·6	
0·3983 (0·1082)	234·8			5·6066 (0·8851)	211·6	0·998
				2·3725 (0.2392)	591·7	0·992
1·1507 (0·1160)	285·0			12·370 (0·683)	323·3	0·986
0·3496 (0·1450)	548·9			36·925 (9·036)	560·8	0·992
				4·8956 (1·2565)	219·0	0·876
		8·625 (3·210)	8·9		173·5	0·554
					375·2	0·999
				1·040 (0·262)	60·4	0·919
				4·970 (2·298)	409·5	0·990
1·438 (0·507)	346·9			19·898 (1·196)	411·7	0·983
				5·774 (0·829)	246·1	0·997
					787·0	0·982
					325·0	0·974

The estimated functions of net output of Other Vehicles were not statistically satisfactory. As an alternative the average of the two ratios of net output to gross output of the two years 1958 and 1963 was multiplied by the gross output of 1962 in order to approximate the net output of 1962.

ASSESSMENT OF MODERN AND OLD VINTAGE OF CAPITAL (1954 Prices.)

INDUSTRY	K_{An}	K_{Ar}	K_{pn}	K_{pr}	K_{A-pn}	Assumed life of P & M
Food, Drink & Tobacco	605.6	327.4	320.1	192.5	612.9	27.5
Mineral Oil Ref.	130.3	127.5	104.1	91.9	153.7	26.0
Other Chemical Industries	792.4	473.9	562.6	316.9	703.7	27.0
Iron and Steel	752.2	309.7	610.1	206.3	451.8	27.0
Non-Ferous Metals	113.4	63.4	78.6	34.4	98.2	27.0
Mechanical Engineering	503.0	287.4	313.1	180.1	477.3	27.5
Scientific Instruments	51.6	25.8	28.7	14.8	48.7	27.5
Electrical Engineering	191.6	103.0	120.4	62.7	174.2	27.5
Electronics	113.8	56.8	74.7	35.8	95.9	27.5
Shipbuilding & Marine Eng.	78.0	59.9	[illegible].4	30.7	97.7	27.0
Motor Vehicles	328.1	226.3	207.8	85.2	346.6	23.7
Aircraft	94.0	10[illegible].3	5[illegible]	64.0	136.1	23.7
Other Vehicles	37.9	49.3	24.0	20.0	63.2	28.5
Other Metal Goods	208.3	15[illegible]	135.7	90.1	226.[illegible]	27.5
Cotton, Flax and Man-made	109.9	177.2	86.7	87.8	200.4	28.2
Wool Textiles	56.0	82.0	38.0	68.9	99.8	28.2
Other Textiles	181.6	251.6	132.0	110.6	301.2	28.2
Leather, Leather Goods	13.1	15.3	7.3	7.2	21.1	27.5
Clothing & Footwear	68.1	69.0	33.1	24.9	104.0	27.5
Bricks, Pottery, Glass, Cement	211.6	142.5	129.3	84.0	224.3	27.0
Timber, Furniture	71.6	67.0	28.9	30.4	109.7	27.35
Paper, printing & Publishing	367.0	216.2	240.0	126.4	343.2	27.6
Other Manufacturing Industries	148.1	111.6	103.9	76.9	155.7	27.5

Key to Abbreviations:

K_{An} and K_{Ar} : Modern and old stocks of all fixed assets.

K_{pn} and K_{pr} : Modern and old stocks of Plant and Machinery.

K_{A-pn} : Stocks of all fixed assets excluding modern plant and machinery.

Table (4.27)

Table (4.28) NUMBERS OF INSURED AND EMPLOYED LABOUR IN 1962

U.K.				Scotland			
Employed			Insured	Employed			Insured
Males	Females	Total	Total	Males	Females	Total	Total
475.7	366.3	842.0	857.0	52.44	43.75	96.19	99.0
26.0	5.4	31.4	32.0	2.20	0.30	2.50	2.6
347.5	138.8	486.3	492.0	24.42	7.95	32.37	33.4
405.7	45.8	451.5	466.0	40.75	4.16	44.91	46.4
110.2	26.9	137.1	139.0	6.45	1.44	7.89	8.1
985.3	212.9	1198.2	1211.0	104.01	18.79	122.80	125.3
95.1	55.7	150.8	152.0	5.10	5.69	10.79	11.0
330.0	165.6	495.4	500.0	12.06	7.97	20.03	20.6
188.4	143.9	332.3	336.0	7.32	3.47	12.55	12.8
237.7	12.7	250.4	264.0	55.43	3.33	58.76	62.2
367.7	57.4	425.1	430.0	7.83	0.97	8.9	9.1
248.7	43.1	291.8	294.0	12.35	2.09	14.57	14.8
146.1	18.0	164.1	166.0	13.76	0.68	14.44	14.7
361.0	190.1	151.1	561.0	19.05	6.60	25.65	26.6
143.9	167.0	310.9	325.0	9.45	15.15	23.45	24.5
88.8	100.4	189.2	193.0	7.80	11.66	19.46	20.0
153.9	187.2	341.1	347.0	20.74	36.94	57.68	59.3
36.4	26.4	62.8	64.0	2.43	1.73	4.16	4.3
158.6	427.3	585.9	295.0	4.48	25.35	30.83	31.6
269.1	82.1	351.2	375.0	19.49	2.97	22.46	23.4
229.7	58.5	288.2	294.0	19.49	4.46	23.95	24.7
407.9	219.4	627.3	632.0	35.20	22.91	58.11	58.9
185.8	121.0	306.8	312.0	12.83	5.09	17.92	18.6

Assessing a price index for all fixed Assets.

The Individual price indexes for various categories of capital as estimated by Cambridge (Program for Growth IV) were used as a basis of assessing a price index for all fixed assets. The capital formation of the three structures of capital; new building work, Plant and Machinery, and Vehicles in the base year 1954 were used as the relevant weights. The assessed price index and the individual price indexes are given below:-

YEAR.	PRICE INDEX OF -			
	ALL FIXED ASSETS.	NEW BUILDING WORK.	PLANT AND MACHINERY.	VEHICLES.
1948	77.8	80.0	77.7	70.0
51	88.5	90.4	86.8	100.0
1954	100.0	100.0	100.0	100.0
55	104.7	106.4	104.6	100.0
56	110.9	110.9	111.4	105.2
57	115.9	115.4	116.3	110.9
58	119.4	119.2	120.1	112.0
59	119.0	117.3	120.8	105.8
60	120.6	117.1	123.1	104.8
61	123.4	116.7	126.6	105.7
62	126.3	124.3	128.7	107.0
63	128.7	128.9	131.1	101.2
64	131.6	132.1	134.1	101.8
65	137.1	136.0	140.4	105.0

Table (4.29)

APPENDIX III

Derivation of gross and net output for 23 industries in Scotland in 1962.

(a) Industrial disaggregation in 1958.

Data on four sub-industries in Scotland are not directly available in the 1958 Census of production and this disaggregation is necessary in order to achieve an industrial breakdown similar to the British sector. These are:

1. Mineral Oil Refining
2. Other Chemicals
3. Aircraft
4. Other Vehicles.

Gross output, net output, and wage bill data on Mineral Oil Refining in Scotland is included, in the 1958 Census of production, with the data given for a number of sub-industries of Chemicals and Allied Industries. The Minimum List Headings of this sub-group are 262, 271 (1), 271 (3) part, 272 (2), 273 and 276.

For the purpose of estimating the output of Mineral Oil Refining, statistics on throughput oils for refining in the U.K. and in Scotland are used. Table 173 (on page 147 of the Annual Abstract of Statistics Vol. 102, 1965) gives the U.K. figures and Table 11 (on page 9 of Vol. 22, Oct. 1963 of the Digest of Scottish Statistics) provides the corresponding figures for Scotland. Thus the ratio of throughput oil for Scotland to throughput oil for the U.K. is multiplied by the values of gross output and net output for the U.K. in order to estimate the gross and net output of mineral oil refining in Scotland as

$$\dot{GO}_{MS} = \frac{TP_S}{TP_B} \times GO_{MB} = \frac{2279}{32933} \times 383$$

$$= £\ 26{\cdot}5\ m$$

and the net output is estimated by

$$\dot{NO}_{MS} = \frac{TP_S}{TP_B} \times NO_{MB} = \frac{2279}{32933} \times 35{\cdot}1$$

$$= £\ 2{\cdot}4\ m$$

where $\dot{GO}_{MS}$, $\dot{NO}_{MS}$, TP_S, TP_B, GO_{MB} and NO_{MB} refer to the estimated gross and net output of mineral Oil Refining in Scotland in 1958, the throughput of oil in Scotland and the U.K., gross and net output of Mineral Oil Refining in the U.K. in 1958.

Since the gross and net output for Chemicals and Allied Industries in Scotland in 1958 are £170·3 m and £50·8 m it follows that the gross and net output for Other Chemicals in 1958 are £143·7 m and £48·4 m respectively.

Since the value of net output and wage bill of the group of industries including Mineral Oil Refining are £20·8 m and £10·9 m respectively, and assuming that the ratio of wage bill to net output in Mineral Oil Refining is equal to the corresponding ratio of the larger group, then the wage bill for Mineral Oil Refining is estimated in 1958 as

$$\frac{2{\cdot}4}{20{\cdot}8} \times 10{\cdot}9 = £1{\cdot}3\ m.$$

It follows that the wage bill for Other Chemicals in 1958 is £9·1 m.

Aircraft manufacturing and repairing, Locomotives and railway track equipment, and perambulators, hand-trucks are included together in the 1958 Census of production. In order to separate the aircraft from the rest of other vehicles, there seems to be no relevant information save the labour fitures in the Digest of Scottish Statitics. Labour figures are given for insured labour only. One figure, however, is available for unemployment for the whole vehicles order which includes for 1958 unemployment of Motor repairs and garages which is excluded from Vehicles in the 1958 Standard Industrial Classification.

Rates of unemployment of the sub-industries in the national statistics were applied to the Scottish sub-industries. The former are derived from insured labour and "numbers registered as unemployment analysis by industry" published in the Annual Abstract of Statistics. Unemployment relating to Motor repair and garages is excluded from the total unemployment of vehicles in 1958 viz 1140. The remainder 600 were distributed as follows: 130 Motor Vehicles and cycles, 330 Aircraft and 140 other vehicles. The estimated employment figures are 6570, 16900 and 19000 respectively.

It is unavoidable to assume that the productivity of labour is the same for Aircraft and all Other Vehicles. The employment figure 24800 which is given by the Census of production for three minimum list headings which includes Aircraft are divided between Aircraft and the rest of other vehicles according to the corresponding figures of employment given by the Digest of Scottish Statistics and adjusted for unemployment.

Thus the Aircraft employment is obtained as

$$24800 \times \frac{16\cdot 9}{26\cdot 23} = 16\cdot 0 \text{ thousands}$$

and the corresponding employment for the rest of Other Vehicles is

$$24 \cdot 8 - 16 \cdot 0 = 8 \cdot 8$$

The ratio of employment in Aircraft just arrived at to total employment of the two sub-industries can be used to divide the gross and net output between Aircraft and the rest of Other Vehicles viz the gross output of Aircraft in 1958 is estimated as

$$42 \cdot 1 \times \frac{16}{24 \cdot 8} = £27 \cdot 2 \text{ m}$$

and the net output will be

$$23 \cdot 4 \times \frac{16}{24 \cdot 8} = £15 \cdot 1 \text{ m}$$

the corresponding figures for the rest of Other Vehicles are £14·9 m and £8·3 m respectively. Therefore the estimated gross and net output for all Other Vehicles (i.e., MLH 384, 385 and 389) are £31·9 m and £13·9 m and the employment figure 15·9.

Moreover the estimated wage bill for Aircraft in 1958 is estimated as

$$\frac{16}{24 \cdot 8} \times 15 \cdot 8 = £10 \cdot 2 \text{ m}$$

It follows that the wage bill for all other vehicles is

$$4 \cdot 3 + 5 \cdot 6 = £10 \cdot 9 \text{ m}$$

(b) Industrial disaggregation in 1962.

The estimation of gross and net output for Scottish manufacturing industries in 1962 is based on the gross and net output figures published by the summary Tables of the 1958 Census of production and the Index of Industrial production published by the Digest of Scottish Statistics. Since the latter provides data on 14 industrial orders while the required industrial breakdown is 23, disaggregation meant that other relevant data has to be used. The labour data, as published by the Digest of Scottish Statistics and Statistics on Income, Prices, Employment and Productivity, was useful as a single basis of disaggregation. Especially because other available physical and value data are insufficient to provide the single basis needed.

However, in using employment data the restrictive assumption that productivity of labour is the same for all sub-industries within an industrial order is avoided in disaggregation. Differences in labour productivity amongst the sub-industries are regarded through using the productivity of the base year 1958 as a basis of estimating intermediate outputs for 1962. The ratio of the intermediate output of a given sub-industry to the total intermediate output of all sub-industries in an industrial order is used in disaggregating the extrapolated output for the industrial order in 1962.

For instance the intermediate gross output of the i^{th} sub-industry in 1962 is estimated as

$$GO^*_{i62} = GO_{i58}/L_{i58} \cdot L_{i62}$$

where GO^*_{i62}, GO_{i58}, L_i refer to the intermediate output in 1962, the gross output in 1958, and the labour in the two years for the i^{th} sub-industry.

The ratios of GO^*_{i62} to the sum of intermediate gross output of all the component industries of an industrial order is this multiplied by the extrapolated gross output of the industrial order to estimate the gross output of the i^{th} sub-industry in 1962.

Table (4.30) provides the main data used and describes the steps taken in deriving the estimates of gross and net output for Scottish Manufacturing Industries in 1962.

Table (4.30) The Derivation of gross and net output for Scottish Manufacturing Industries in 1962.

Industry	Index of Industrial Production in 1958 1954 = 100	in 1962 1954 = 100	1958 = 100 2/1·100	Gross Output 1958	1962 4·3/100	Net Output 1958	1962 6·3	Labour 1958	1962	Intermediate gross output 4/8·9	Percentage of sub-industry to industry order intermediate output	Estimated gross output of sub-industries 11·5	Estimated net output of sub-industries 6/4·12
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Food, Drink & Tobacco	108	121	112	468	525·1	110·0	123·2						
Chemical & Allied Industries	122	148	121·3	170·3	206·6	50·8	61·6						
Mineral Oil				26·2		2·4		3·3	2·6	20·64	13·18	27·2	2·5
Other Chemicals				143·7		48·4		35·3	33·4	135·96	86·82	179·4	59·1
Metal Industries	90	91	101·1	220·4	222·8	65·8	66·0						
Iron and Steel				189·4		58·1		54·3	46·4	127·66	77·04	171·6	52·6
Non-Ferous Metals				31·0		7·7		6·6	8·1	38·05	22·96	51·2	13·4
Engineering and Electrical Goods	110	128	116·4	278·8	325·8	140·9	164·0						
Mechanical Engin.				218·3		110·6		119·8	125·3	228·1	73·83	240·9	121·0
Scientific Inst.				12·6		7·5		10·0	11·0	13·86	4·49	21·0	12·3
Electric Eng.				38·8		17·2		17·2	20·6	46·47	15·4	39·4	17·4
Electronics				10·1		5·6		6·3	12·8	20·52	6·64	24·5	13·3
Ship Build. & Main Eng.	100	82	82	133·3	109·3	52·3	42·9						
Vehicles	90	113	125·6	69·5	87·5	33·0	40·5						
Motor Vehicles				10·4		4·0		6·7	9·1	14·13	22·9	20·1	7·7
Aircraft				27·2		15·1		17·2	14·8	23·41	38·09	33·2	18·2
Other Vehicles				31·9		13·9		19·6	14·7	23·93	38·92	34·0	14·6
Other Metal Goods	104	105	101	52·8	53·3	22·9	23·1						
Textiles	91	96	105·5	186·4	196·7	64·9	68·5						
Cotton, Flax, etc.				41·8		16·0		24·5	24·5	41·8	22·94	45·1	17·4
Wool				44·1		13·4		18·7	20·0	47·17	25·88	50·9	15·5
Other Textiles				100·5		35·5		63·9	59·3	93·27	51·18	100·7	35·6
Leather	87	87	100	9·6	9·6	2·9	2·9						
Clothing	105	117	111·4	34·4	38·3	14·2	15·8						
Bricks, Pottery etc.	101	115	113·9	40·6	46·2	19·9	22·7						
Timber, Furniture	88	87	98·9	40·5	40·1	15·7	15·5						
Paper, Printing etc.	101	112	110·9	113·7	126·1	49·7	55·1						
Other Manufacturing Industries	96	101	105·2	39·3	41·3	13·9	14·6						

Table (4.32) ESTIMATING THE STOCK OF CAPITAL FOR

INDUSTRIES.	1958 Net Output.		1958 Wage Bill.		3/1	2/4
	(1) U.K.	(2) Scotland.	(3) U.K.	(4) Scotland.	(5) U.K.	(6) Scotland.
Food, Drink & Tobacco	916.5	110.0	367.0	40.1	.4004	.3646
Mineral Oil Ref.	35.1	2.4	14.7	1.3	.4188	.5420
Other Chemical Industries.	700.6	48.4	276.1	19.1	.3941	.3955
Iron & Steel.	549.7	58.1	300.9	31.6	.5474	.5439
Non-Ferous Metals	139.5	7.7	81.4	4.9	.5835	.6364
Mechanical Engineering	1015.0	110.6	614.1	59.5	.605	.538
Scientific Instruments.	112.6	7.5	65.4	5.0	.5808	.667
Electrical Engineering.	405.0	17.2	238.6	15.2	.5891	.8837
Electronics.	210.0	5.6	139.5	3.9	.6634	.6964
Shipbuilding & Marine Eng.	227.0	52.3	173.7	41.2	.7652	.7878
Motor Vehicles.	410.5	4.0	249.9	2.6	.6088	.6667
Aircraft.	284.8	15.1	189.7	15.8	.6661	.6755
Other Vehicles.	123.0	13.9	93.4	4.5	.7594	.7842
Other Metal Goods.	439.3	22.9	254.7	12.8	.5798	.559
Cotton, Flax & Manmade.	225.8	16.0	153.5	10.6	.6798	.6625
Wool Textiles.	136.7	13.4	81.9	6.9	.5991	.5149
Other Textiles.	252.8	35.5	141.4	21.3	.5593	.60
Leather, Leather Goods.	43.3	2.9	27.5	1.8	.6351	.6207
Clothing & Footwear.	308.3	14.2	204.4	10.2	.663	.7183
Bricks, Pottery, Glass, Cement.	296.6	19.9	174.9	11.4	.5897	.5729
Timber, Furniture.	211.9	15.7	140.6	10.7	.6635	.6815
Paper, Printing & Publishing.	577.0	49.7	337.0	29.2	.5841	.5875
Other Manufacturing Industries.	227.4	13.9	133.4	8.8	.5866	.6331

SCOTTISH MANUFACTURING INDUSTRIES. Table (4.32) cntd.

B			Net Stock of Capital.					
1-(5)	1-(6)	(9)	All Fixed Assets.		Plant & Machinery.		Other Structures.	
U.K. (7)	Scot-land. (8)	$\frac{K_{AS}}{K_{AB}}$	U.K. (10)	9x10 Scot-land. (11)	U.K. (12)	9x12 Scot-land. (13)	U.K. (14)	(11)-(13) Scot-land. (15)
.5996	.6354	.0996	933	93.0	512.6	51.1	420.4	41.9
.5812	.4580	.0489	257.8	12.6	196.0	9.6	61.8	3.0
.6059	.6045	.0660	1266.3	83.6	909.3	60.0	357.0	23.6
.4526	.4561	.0808	1061.9	85.8	818.4	66.1	243.5	19.7
.4165	.3636	.0904	176.8	16.0	113.0	10.2	63.8	5.8
.3950	.4620	.0823	790.4	65.1	493.2	40.6	297.2	24.5
.4192	.3333	.0966	77.4	7.4	43.5	4.2	33.9	3.2
.4109	.1163	.0973	294.6	28.7	183.1	17.8	111.5	10.8
.3366	.3036	.0392	170.6	6.7	110.3	4.3	60.3	2.4
.2348	.2122	.2197	138.1	30.3	71.1	15.6	67.0	14.6
.3912	.3333	.0147	554.4	8.2	293.0	4.3	261.4	3.9
.3339	.3245	.0582	194.3	12.3	122.2	7.1	72.1	4.2
.2406	.2156	.1490	87.2	13.0	44.0	6.6	43.2	6.4
.4202	.4410	.0390	362.5	14.1	225.8	8.8	136.7	5.3
.3202	.3375	.0760	287.1	21.8	174.5	13.3	112.6	8.6
.4009	.4851	.0739	138.0	10.2	107.1	7.9	30.9	2.3
.4407	.4000	.0992	433.2	43.0	242.6	24.1	190.6	18.9
.3649	.3793	.0450	28.4	1.3	14.5	0.7	13.9	0.6
.3370	.2817	.0437	137.1	6.0	58.0	2.5	79.1	3.5
.4103	.4271	.0525	354.1	18.6	213.8	11.2	140.3	7.4
.3365	.3185	.0644	138.6	8.9	59.3	3.8	79.3	5.1
.4159	.4125	.0694	583.2	40.5	366.4	25.4	216.8	15.1
.4134	.3669	.0493	259.7	12.8	180.9	8.9	78.8	3.9

CHAPTER V

THE MODEL

THE MODEL

This chapter provides the link between both Chapters III and IV (which deal with the previous work and data implementation) and the proposed model in its general form, and prepare for the gradual application of the model on British and Scottish Manufacturing Industries. It is divided into three sections, each with a distinct function.

Section (A) is meant to emphasize the threat imposed by the heterogeneity of the available data for the appropriateness of the outcome of the investigation whose broad statistical and policy features are drawn by Section (B) below. It stresses the need for rather than describes the effort spent in implementing the data by Chapter III in order to reduce as far as possible the heterogeneity involved in the published data. In short it is mainly concerned with the distortion caused by heterogeneity of data for inter-industry and inter-regional analysis. The likelihood of a remainder of heterogeneity in the data prepared for the investigation is indicated but ways and means of testing for their effect is lacking mainly due to insufficiency of data.

Section (B) takes over the task of dealing with the statistical and policy implications of the main sources of bias resulting from errors of specifying the considered functional relationships as well as the errors of specifying the variables involved. It is shown that the biases are attributable to ignoring essential factors that are mainly of an economic nature. It is particularly indicated that ignoring scientific and technological effort is an omission error of specification in the production function and that ignoring the distinction between the main activities of scientists and technologists involves an error of specifying the influential variable of scientific and technological effort. The implication of the sources of bias for policy consideration are also regarded.

Section (C) intends to take off from the previous work (reviewed in Chapter III) to formulate in general terms the present model in such a way as to include the main features which are proposed by Section (B), viz stress the necessary improvements in the accuracy of the functional specification as well as the specification of the variables. However, Section (C) leaves the gradual and combined application of the suggested improvements to Chapters VI - XI inclusive.

A: Sources of statistical bias:

The general feeling is that an econometric study of the main factors determining growth and technical efficiency is both interesting and useful for each country, region and industry. What is important to add is that applying the same technique for each of two or more regions for the purpose of inter-regional comparison is even more stimulating. It goes without saying that the difficulties encountered in the latter situation are much more profound as well as less amenable to solution in practice, mainly because of the present state of data collection.

It may be useful to emphasise from the start that the theoretical requirements of highly reliable statistical estimates for inter-regional comparison is difficult to attain in practice, at least with the data presently available. Nevertheless, it seems naive to rule out the use of the available information just because it is short of the ideal. The main features of the study which are most likely to suffer, though, are: the degree to which conclusions may be detailed, and the possible generalization based on these conclusions. (See Chapter XI.).

From a statistical point of view it is accepted that drawing two samples out of the same population scarcely provides the same value for the estimated parameters. In the absence of extreme observations in either sample, significance tests, "Chow" statistics in the present situation, should indicate that the two sets of estimations are not significantly different.

Three main factors may be singled out as potential dangers which threaten the homogeneity requirements and thus endanger the accuracy of the subsequently estimated parameters of a given function as well as the comparability of the estimated functions for inter-regional comparison. These are:-

(a) Sampling technique and sampling units and coverage

(b) Data availability, aggregation over industries and implementation

(c) Other distorting factors (mainly of an economic nature).

The first two sets of factors are attributable to the potential distortion of available and used data, while the third set of factors deals with the main sources of bias introduced to the estimated parameters via wrongly specifying the functional relationship as well as the erratic specification of the variables involved in the considered function. Because of the paramount danger of ignoring the main factors of this set the following section (B) is devoted to them.

The comparability of the variables for either or all inter-industry, inter-temporal and inter-regional functions will be endangered by:-

(a) The use of data derived from different sources which survey, or publish data, on the basis of different:-

  (i) sampling units; such as establishments, firms, concerns, etc.

  (ii) lower limit of the size of the sampling units,

  (iii) standard industrial classification,

  (iv) industrial breakdown.

(b) The use of data derived by the same source that introduces, temporal changes similar to (i) and (vi) and/or changes the definition of the variable asked for.

Some of these sources of data's distortion have been regarded in Chapter IV on data implementation and, where available data and time allowed, steps have been taken to reduce the heterogeneity involved.

The second aspect which may affect the comparison between regions is the availability of collected information. In the present situation, for example, more published data is available and in a less aggregated manner for British Manufacturing Industries in comparison with the data obtainable for Scottish Manufacturing Industries.

Many of the variables must be estimated and/or disaggregated for Scotland to make possible a comprehensive comparison between Scottish and British Manufacturing Industries, while it was necessary to make some disaggregation for the latter as well. By and large, the collected (and available) data are superior to estimated data though it may be possible to arrive at estimates that enjoy a great confidence, provided these are based on the most relevant information and the use of sophisticated techniques of estimation.

Confidence in the estimated data may be determined in the light of:-

(i) The plausibility of the estimates as a whole when compared with 'a priori' information.

(ii) The sharpness, (i.e. significance), and the plausibility of the sign of the coefficients estimated in the sought relationships,

(iii) The explanatory power (corrected for degrees of freedom) of the estimated relationships.

B: Statistical and Policy Implications of the wrong Specification of Input Factors and the less Accurate Specification of the production function.

The aggregate production function as expressed by equations (5.21) and (5.22) below implies that the labour and capital factors are more or less homogeneous. That this assumption is highly implausible is a well known fact, but nevertheless, this is by-passed in the majority of empirical work. Owing to the dangers of not correcting for the heterogeneity involved, serious policy implications and statistical bias may be involved.

Within the productive activities, the most important causes of the wrong specification in the measurement of input factors involve ignoring the following factors which are mainly of an economic nature:-

(i) a distinction between skilled and non-skilled workers,

(ii) a distinction between male and female employees,

(iii) a distinction between the number employed and average hours,

(iv) a distinction between the components of capital structure,

(v) a distinction between various qualities of capital

An incomplete specification of the aggregate production function is also caused by ignoring:-

(i) correction for the degree of capacity utilization, and

(ii) an explicit introduction of scientific input.

On the other hand, if the above factors are regarded, one may achieve

(i) a better understanding of the factors responsible for economic growth and the relative contribution of each;

(ii) a considerable decrease in the harmful effect of the factors which are likely to distort inter-industry, inter-temporal and inter-regional studies.

This could imply greater benefits of the derived conclusions for the purpose of national as well as regional policy recommendation. This could lead to an improvement in the estimates on which policy may be based.

(a). Statistical Treatment:

This section deals with two types only of errors of specification, viz. errors of specifying variables and the inaccurate specification of the function. A third source of specification error, errors of observation, is generally a result of inaccuracies in the data used and has been summarised in Section A above. The steps taken to reduce the detrimental effect of such errors has been described in Chapter IV. A fourth type of specification error, multicollinearity, is that resulting from high correlation between some of the explanatory variables to the extent of reducing the order of the moment matrix. In line with other studies, the existence of multicollinearity at certain stages of the study has not led us to abandon the search for an accurately specified function, but a priori theoretical knowledge has been used in specifying the function so as to reduce where possible the adverse effects of multicollinearity.

The statistical treatment of the bias resulting from errors of specification of the types dealt with here is based on Theil, 1958. Suppose that the correctly specified function is

$$Y = XB + U \qquad (5.1)$$

where Y is the dependent variable and X is the matrix of correctly specified explanatory variables; B is a parameter column vector, U is a vector of errors. Assume further that X is non-stochastic and that $E(U) = 0$, and $E(UU') = \sigma^2 I$

Let the incorrect specification of (5.1) be

$$Y = Z\Gamma + V \qquad (5.2)$$

where Z is the matrix of the explanatory variables (wrongly or accurately specified) used in estimating the function (5.1)/ Γ are the corresponding coefficients and V is the vector of errors.

We may define Γ as the mean value of the vector of least squares regression coefficients γ where

$$\gamma = (Z'Z)^{-1} Z'Y. \tag{5.3}$$

From (5.1) and (5.3)

$$\gamma = (Z'Z)^{-1} Z'XB + (Z'Z)^{-1} Z'U \tag{5.4}$$

Taking the expected values of both sides of (5.4), we find

$$E(\gamma) = (Z'Z)^{-1} Z'XB \tag{5.5}$$

defining $P = (Z'Z)^{-1} Z'X$ and $E(\gamma) = \Gamma$, therefore

$$\Gamma = PB \tag{5.6}$$

where P is the coefficient matrix of the least squares regressions of the correct explanatory variables on the erroneous ones, i.e.

$$X = ZP + V_2 \tag{5.7}$$

where V_2 is the corresponding vector of least squares residuals.

Suppose that there is no omission error, in this case the number of explanatory variables is the same in both Z and X matrices. It follows that the matrix P is a square one. However, let there be one difference, viz. the first of the variables of Z, z_1 differs from the corresponding variable x_I. Although the matrix P becomes a unit matrix except for the first column, which consists in general, of non-zero elements, it will be seen that in general all components of γ are affected by this incorrect specification. Thus

$$E(\gamma)_j = B_j + p_{j1}B_1 \qquad j = 2, 3 \ldots m \tag{5.8}$$

where $E(\gamma)_j$ and B_j are the jth components of $E(\gamma)$ and B respectively and the p's are the coefficients of the auxiliary regression

$$x_1 = \sum_{h=1}^{m} p_{h1} z_h + e \qquad (5.9)$$

$$h = 1, 2 \ldots\ldots m$$

z_1 is the wrongly specified variable, which is used in the estimation instead of the correctly specified variable x_1. M is the number of X columns and m is the number of Z columns.

The difference

$$(E\gamma)_j - B_j = p_{j1} B_1$$

may be called the specification bias of the coefficient $E(\gamma)_j$. It is to be noted that all coefficients $E(\gamma)_j$ except $E(\gamma)_1$ have no specification bias if their variables are all uncorrelated with the incorrectly specified variable x_1. Since this condition is difficult to obtain in economics, it is usual rather than not that a mis-specification of one or more of the variables involved in the estimation of a given function will lead to bias in all the estimated coefficients.

In addition to their undesirable effect in biasing the estimated coefficients errors of specification generally, and omission errors in particular, lead on the average to an overstatement of the residual variance. Recalling that, amongst other things, this study is concerned with breaking down the residual element of the aggregate production function usually known as technical efficiency in cross-section studies and technological progress in time series analysis. Therefore, it becomes obvious that in addition to realising the objective of improving the accuracy of the input factors as well as the production function specification, a considerable part of the residual is also explained.

The sample variance of the least-squares residuals of (5.3) is

$$(Y-Z\gamma)'(Y-Z\gamma) = Y'[I-Z(Z'Z)^{-1}Z']Y = (XB+U)'[I-Z(Z'Z)^{-1}X'](XB+U) \qquad (5.10)$$

If it is assumed further that Z is non-stochastic, then the mean value of the sample variance is

$$E\left(\frac{1}{n}(Y-Z\gamma)'(Y-Z\gamma)\right) = \frac{1}{n}(XB)'\left[I-Z(Z'Z)^{-1}Z'\right]XB + E\left(\frac{1}{n}U'\left[I-Z(Z'Z)^{-1}Z'\right]U\right) \quad (5.11)$$

$$\geqslant E\left(\frac{1}{n}U'\left[I-Z(Z'Z)^{-1}Z'\right]U\right) = \sigma_u^2 \frac{n-m}{n}$$

σ_u^2 being the variance of the components of U and m the number of columns of Z. The above result implies that the residual variance of the incorrect specification, when corrected for loss of the degrees of freedom by multiplying by n/n-m, is on the average larger (at least not smaller) than the residual variance of the correct specification. Similarly $\bar{R}^2$ is then smaller on the average. In this sense therefore the criterion of maximum multiple correlation leads on the average to the correct choice of function.

However, if no independence can be assumed between each row of Z and the corresponding component of U, then deviation (5.11) is no longer applicable and the criterion of maximum $\bar{R}^2$ is not necessarily adequate on the average.

The effect of mis-specification of one input factor in biasing the estimates of the coefficients of other input factors in general, and the estimation of the coefficient of technological progress in the production function in particular, will now be considered. Assume that the production function is linear, homogeneous and its correct specification is

$$Y = B_1x_1 + B_2x_2 + B_3x_3 + B_4x_4 + u \quad (5.12)$$

where Y, x_1, x_2, x_3 and x_4 stand for output, plant and machinery, other capital structures, labour and time; the B's are the true parameters of the production function, and u is the residual term.

If the distinction between plant and machinery and other structures of capital is ignored, the estimated production function takes the form

$$Y = \gamma_1 z_1 + \gamma_2 z_2 + \gamma_3 z_3 + v \qquad (5.14)$$

when z_1, z_2, and z_3 represent capital, labour and time, γ's are the corresponding coefficients, and v is the residual term. It will be seen that replacing the two structures of capital x_1 and x_2 by total capital z_1 leads to biasing all γ's in general and in particular to bias γ_3.

From (5.6)

$$E\begin{bmatrix}\gamma_1\\ \gamma_2\\ \gamma_3\end{bmatrix} = \begin{bmatrix}p_{11} & p_{12} & 0 & 0\\ p_{21} & p_{22} & 1 & 0\\ p_{31} & p_{32} & 0 & 1\end{bmatrix}\begin{bmatrix}B_1\\ B_2\\ B_3\\ B_4\end{bmatrix} \qquad (5.15)$$

It is noted that the P matrix is no longer a square one and only two of its four columns correspond to the columns of an identity matrix. Then

$$E(\gamma)_j = B_j + p_{j1}B_1 + p_{j2}B_2 \qquad (5.16)$$

The time coefficient in particular will be

$$E(\gamma)_3 = B_4 + p_{31}B_1 + p_{32}B_2 \qquad (5.17)$$

Re-writing (5.12) as

$$Y = (B_1 - B_2)x_1 + B_2(x_1 + x_2) + B_3x_3 + B_4x_4 + u \qquad (5.18)$$

and recalling that $x_1 + x_2 = z_1$ and that $x_3 = z_2$ and $x_4 = z_3$, then

$$E\begin{bmatrix}\gamma_1\\ \gamma_2\\ \gamma_3\end{bmatrix} = \begin{bmatrix}p_{11} & 1 & 0 & 0\\ p_{21} & 0 & 1 & 0\\ p_{31} & 0 & 0 & 1\end{bmatrix}\begin{bmatrix}B_1 - B_2\\ B_2\\ B_3\\ B_4\end{bmatrix} \qquad (5.19)$$

therefore

$$E(\gamma)_3 = p_{31}(B_1 - B_2) + B_4 \qquad (5.20)$$

It is to be noted that (5.20) is obtained according to a linear production function. Form (5.17) can be used to arrive at the bias in the Cobb-Douglas case. However, the bias in the case of a Cobb-Douglas production function is expected to be close to (5.20) in view of the satisfactory performance of both the linear and Cobb-Douglas forms in estimating the production function for British and Scottish manufacturing industries (see Chapter VI). In the Cobb-Douglas form B_1 and B_2 are the output elasticities with respect to plant and machinery and other structures of capital. Estimating the production functions for British and Scottish manufacturing industries indicates that B_1 exceeds B_2. B_1 is several times as large as B_2 in the two sectors respectively. Moreover p_{31} (which is now the coefficient of time in the auxiliary regression of log x_1 on log z_1, log z_2 and time), is generally positive. Then the mis-specification of capital leads generally to an upward bias in the estimated rate of technological progress.

(b). Policy Implications:

One of the difficult tasks of planners is to reconcile various conflicting, though desirable, objectives, relating to such matters as the rate of economic growth, the level of employment and foreign trade. Fiscal and monetary policy and direct controls are used to direct economic resources to achieve the desirable objectives and avoid serious repercussions. These policies have for long been based mainly on influencing the demand side. The finding based on studying the supply side seems to be worth regarding too (See Chapter VIII). Moreover, apart from economic indicators which are useful in the short term, formulating of long term policy is mainly based on estimated potential levels of resources and outcome.

To a large extent the healthier the basis on which the estimates are reached the greater the probability of success in any action taken earlier (on the basis of a carefully drawn plan) to meet future requirements.

The production function is considered to be useful for prediction for a period up to ten years.(1) If the labour factor is treated as homogeneous factor bias may occur in the future estimates of potential output based on wrongly specified labour requirements. For instance, disregarding the distinction between skilled and non-skilled workers may lead to an underestimation of the full employment output in future years, should the balance be shifted in favour of skilled labour over time.

A situation may develop in which the expansion in the labour force may not be sufficient to fulfil the requirements of a higher rate of economic growth.

The demand for drawing on the pool of married women would follow the exploitation of labour-saving devices, along with all the other possible ways of increasing labour productivity. If the large difference between the productivity of males versus females is ignored it may well be that the decision to attract a given number of married women, other things being equal, will be less than sufficient to relieve a given shortage.

On the other hand if there is a tendency for the number of female employees to grow at a rate faster than the males, e.g. as a result of changes in habits or increasing baby-care facilities, etc., a full employment output potential that disregards the difference in the sex composition might also be overestimated.

Feldstein (1967) has considered the possible effect of the bias introduced by measuring the labour input by manhours instead of

---

(1) See, e.g. Kuh, 1966; and Nelson, 1964.

distinguishing between the number employed and the average hours. His production function estimates based on all United Kingdom industries gave consistent magnitudes though not significant estimates for the average hours coefficient. They indicate that the average hours coefficient is larger than the labour and capital coefficients added together. Denison's data on the United States of America reveals that there is a downward trend in average hours. Feldstein's conclusion is that there will be a downward bias in the estimated rate of technological progress based on estimates that disregard such a distinction.

If the direction of bias is in line with what Feldstein envisaged, within a decade the following policy implication will result. Provided that the output elasticity with regard to manhours exceeds the elasticity in respect of number employed, any downward trend in hours will lead to an over-estimation of the full employment output in future years. Similarly, in seeking to determine an optimal level of hours, or rate of its decrease, a failure to distinguish between average hours and employment would lead to an under-estimation of the fall in the rate of growth due to a higher rate of decrease in working hours.

But is it true that, within one decade, this will be the case for Britain? The answer indicated by the Ministry of Labour Gazette is "NO". Considering the period from October 1948 to October, 1959, the index of average hours (1948 = 100) rose to 103.7 for the manufacturing industries and to 103.9 for the economy as a whole. However, the average hours worked for manufacturing fluctuated from 104.7 in 1956 to 101.7 in 1958. "At the end of the 13-year period average weekly hours worked in all industries covered by the enquiries were 47.4 as against 46.7 at the start and this, despite a reduction estimated at between 3 and 3½%

in the length of the normal working week in these same industries".[(1)]

On the basis of this evidence, it seems that the direction of the bias on technological progress due to the wrong specification of labour and the resultant policy implications arrived at by Feldstein, should be reversed. It may very well be that within two or three decades the average weekly hours may resume its long run downward trend. But it is evidently not the case according to recent past experience.

The case may be even stronger when the bias resulting from ignoring the distinction between various components of the structure of capital is considered. If the elasticity of output with respect to plant and machinery is considerably higher than the elasticity with respect to other types of capital (as is evidently the case), then distinguishing between various components of capital structure is essential. From a policy point of view, this may lead to:-

(i) avoiding over or underestimation of capacity output at a future date, especially if the development is such as to allow the rate of forming plant and machinery to overtake or fall short of the rate of forming other types of infra structures;

(ii) the possibility of adopting a discriminatory preference towards the rate of growth of components of capital structure in such a way as to maximize the benefit of resources allocated to capital formation;

(iii) a fuller knowledge of at least one of the ways of improving the efficiency of capital and possibly the efficiency of labour.

Furthermore, if the benefits of avoiding distortions resulting from wrongly specifying capital through ignoring the distinctions between high

---

(1) The Ministry of Labour Gazette, Vol.70, 1962, pp. 255-263. "Trends in Average Earnings and Hours of work of Men Manual Workers in the United Kingdom. (1948-1961)".

quality and inferior capital are added to the benefits of correcting for the structure of capital, the combined gain from a policy point of view is greater still.

It is indicated by this study that the output elasticity with respect to plant and machinery is greater than the elasticity with respect to other types of capital. Also the estimated output elasticity with respect to new capital (as well as new plant and machinery) is greater than the elasticity with respect to old capital (and old plant and machinery). It will become obvious that ignoring structural and qualitative aspects of capital may result in an upward bias in the estimated technological progress (or technological efficiency) if the structure and vintage of capital is changing in favour of plant and machinery and a greater degree of modernization, respectively. (See Chapters VI and VII.)

Through an explicit introduction of the degree of capacity utilization it is possible to correct a further mis-specification of the production function and to improve further the specification of input factors, thus eliminating an important source of bias in estimating technological progress (or technological efficiency). As will be seen below (Chapter VIII), the size and significance of the elasticity of the degree of capacity utilization may prove useful from policy point of view.

If the process of adjusting productive capacity has been under way towards satisfying a given (and possibly lower) level of demand, then ignoring the degree of capacity utilization might not involve a serious bias. This further implies that the greater the disequilibrium the greater will be the bias involved in assessing technical efficiency (or technological progress) if no correction is made for the degree of capacity utilization. Furthermore, the effect of not correcting for the degree of capacity utilization is shown to introduce a downward bias into the estimation of the coefficient of the factor which is measured as a stock rather than a flow.

C: The Model:

Most recent work on technological change has been concerned with measurement errors in the input factors and the bias introduced through the wrong specification of these input factors. It is obvious that the productive system is the appropriate framework for the present investigation and that the production function is therefore the relevant concept rather than decision (or marginal productivity) functions.

It may be interesting to draw a brief comparison between distinct groups of growth models and the one it is proposed to apply. It is desirable, moreover, to present the functions formally rather than to go into their mathematical specification. Only in certain problems shall we have to specify the production function explicitly. The reason for preferring the general functional form at this stage is that it is mainly through experimentation that the appropriate form will be arrived at. Otherwise each form would imply a set of assumptions which might be unnecessarily restrictive. The following form is frequently used in the formulation of growth models:

$$O = f(L, K, A) \tag{5.21}$$

where O, L, K and A represent output, labour capital and technological efficiency in cross-section situations or technological progress in time series studies. As a residual factor A represents in addition to all the biases in measuring and specifying conventional input factors and output, the effect of intangible factors together with the fruits of investment in technology. Many studies are being undertaken at present with a view to explaining some of the factors determining the value of A. Empirical evidence indicates that A accounts for between 80% and 90% of the observed increase in labour productivity in the United States economy.(1)

---

(1) See, e.g. Kendrick (1961). Abramovitz (1956), Solow (1957) and Massel (1961).

Three main, quite different, assumptions are used in models concerned with technological change assessment. The first regards all technological change as being of an organizational (or disembodied) nature which must be treated as autonomous shifts in the production function that takes the form[1]

$$O = Af(L, K) \tag{5.22}$$

The main assumption of that model is that technology leads to an isoelastic shift in (rather than a movement along) the production function, thus leaving unaffected the shape of that function. Such an autonomous form of technological progress is supposed to occur without the aid of new input factors, and, especially without the aid of capital formation that embodies the latest technical improvement. This technical improvement consists of organisational changes in the methods of combining and rearranging existing factors of production.

The second assumption states that the rate of technological progress is influenced by the rate of capital formation, probably in the form of a direct relationship between changes in technology and gross investment. The hypothesis underlying such an assumption is that innovations are frequently incorporated in capital items which represent replacement of or additions to existing plant and equipment.[2] Thus the quality of capital, (as well as its structure) must be considered in measuring the capital factor. In the vintage model, as it is known, new assets are assumed to be "better" assets, thus the distinction between various layers of assets

---

(1) Solow, (1957), Domar (1957), Hicks (1932), Nelson & Phelps (1965) etc. It is to be noted that equation (5.22) is a general form of expressing the assumption of neutral technological change, it is used with modification to serve the requirements of the stated studies.

(2) See, e.g. Johansen (1959) and (1961), Solow (1959), and Massel (1964).

is of prime importance, e.g.

$$O = f\ (L,\ GI,\ A) \qquad (5.23)$$

where GI represents the integrated value of gross investment over the life span of fixed assets corrected for decay.

Another main difference between this "induced" type of technological change and the "autonomous" hypothesis is that A is formally treated in the former case as an argument in the function(form (5.23)) rather than exogenously determined (form 5.22)) in the latter case. It is worthwhile to note that in either case A acts as a catch-all for the variables left out of the specification of the production function, in addition to representing the bias caused by wrongly specifying conventional input factors. However, A is bound to lose part of its explanatory power in "vintage" models through accounting partly for qualitative improvements in capital.(1)

The third hypothesis regards the improvement (mainly of labour) through "learning by doing" as the cause of technological change. In the "progress" models, the evidence provided indicates that the average and marginal input requirements are a declining function of the volume or accumulated output up to some point in the production run.(2) Except for allowing for the progress rates of different types of input factors (i.e. allowing for factor substitution), this model would not add much practical progress over the autonomous hypothesis. On the rather negative side it implies that output in physical terms can be increased by restricting product lines, limiting entry of new firms, and through the adherence to known products and production techniques until the benefits from "learning by doing" are realised.

---

(1) The other aspect of quality improvement is the rate of technical improvement in the production of new capital goods.

(2) See Arrow (1957; Wright (1936).

Due to the obvious limitations of each one of the three models briefly sketched above, the present study favours a more general model.(1) That model recognises the possibility of incorporating some technological progress (or technical efficiency) in the newly produced capital equipment, education and human experience. However, it advances, moreover, that a significant part of technological progress (or technical efficiency) may be accounted for by introducing explicitly various forms of scientific activities as factors of production. Some of these factors contribute to current production activity and the remaining are devoted to improving future technology, see chapters X and XI.

In order to indicate the necessary improvements in the accuracy of functional as well as variable's specification in line with the proposals made in section B and so as to meet the requirements of the model as just described, in its general form, the model can be expressed as:-

$$O = f(k_{ij}, \ldots\ldots; L_1, \ldots\ldots; f_s, f_e; m_s, m_e; r_s, r_e; c; a) \qquad (5.24)$$

where K_i is the measurement of the i^{th} type of capital structure of the j^{th} vintage, L_i refers to the various categories of the labour force broken down according to age, sex, education, training and skill, etc. f_s, f_e represent the qualified scientific manpower of science degree and technologists respectively, engaged on the shop floor; m_s, m_e represent the employment of qualified natural scientists, (and probably social scientists), and technologists engaged in managerial activities, r_s, r_e, r_o refer to the number of scientists, technologists and other supporting staff engaged in research and development (either in a simple lagged form or as a distributed lag). c represents the degree of capacity utilization.

---

(1) See Chapter III above.

The "residual factor" is supposed to explain a much lower proportion of the total variation than its counterpart in equations (5.21) and (5.22).

Notwithstanding that the model explained by (5.24) has to be modified in certain respects it is known for instance that the term capital combines together a large number of assets bought at different times and performs widely different functions. In spite of the theoretical attraction of regarding each asset of a given vintage as distinguished from the others, in practice a varying degree of aggregation is inevitable. Thus the distinction between each vintage of capital has to be reduced to a distinction between a few layers of vintages only because of the small number of observations and because of multicullinearity. This and other simplifications of the model are discussed in succeeding chapters.

CHAPTER VI

THE MEASUREMENT OF CAPITAL

I-THE VIVTAGE OF CAPITAL

THE MEASUREMENT OF CAPITAL

I. Capital Vintage.

A. Introduction:

One of the preoccupations of earlier studies was to quantify or approximate the stock of capital[(1)], but they only managed to quantify (to a certain extent) the quantity of capital rather than its quality. The perpetual inventory, (Redfern, 1955), and replacement value as approximated by the firm's insurance, (Barna, 1957), are two well known methods. But even if measuring capital by quantity were acceptable for some applications it does not follow that the stock of capital would be homogeneous. The fact that in practice various types of capital assets are not used in fixed proportions, and that the assets used can vary from the most up-to-date to the quite aged ones, means that the use of the stock of all assets as a measurement of capital involves difficulties of heterogeneity.

It is made clear in Chapter V that the errors of specification in the measurement of capital tends to introduce statistical bias into the measurement of technical efficiency and the coefficients of the estimated production function. In addition, if the errors of specification are ignored, serious policy implications may arise. In this chapter the

---

(1) In National Income and Expenditure, 1967, published by the C.S.O. it is stated "The present estimates are a development of those used by Mr. Redfern ... They have been revised to incorporate the estimates... given by Geoffrey Dean ... Estimates or assumptions are made about the average length of life of each class of asset separately distinguished. Gross fixed capital formation is then estimated for each class of asset for L years prior to Y., where L is the average life of the class of asset in question and Y is the year for which the gross stock and capital consumption are to be estimated. Price Indices are applied to those estimates in order to convert them to constant prices. They are then aggregated for L years to obtain the estimate of capital stock. Division by L gives the estimate of capital "consumption" ...

vintage of capital will be dealt with. The structure of capital will be treated in the next chapter.

The quality of capital is difficult to deal with since the resultant effect on firms' capital input will depend not only upon the vintage of the stock of capital but also upon the rate of improvement in capital goods. There are thus two dimensions of quality, of which only the vintage of capital has attracted attention recently, perhaps because the required data is less difficult to obtain compared with the data needed to estimate the rate of improving capital goods.

Modern capital is better than older capital not only because it renders more services in terms of length and duration of its operation but, more importantly, newer capital is supposed to be much more efficient since it embodies the latest technological improvements. The vintage or the Johansen model is useful in providing a distinction between various vintages of capital and in accounting for one dimension of the quality of capital. It thus provides an important step towards reducing the heterogeniety of capital.

It is to be noted that the average efficiency of the stock of capital that is accumulated during a period of an accelerated rate of innovation (in capital producing industries) is likely to be higher than it would have been with a slower rate. Thus either an accelerated rate of improvement in capital producing industries and/or an increased rate of capital modernization would lead to an increase in the average efficiency of capital in use; the main assumption being that the newly produced capital equipment embodies the most up-to-date technological advance.(1)

---

(1) It does not necessarily follow that all technological progress is embodied in newly produced capital equipment (see chapters III and XI). Also it is implicit that diminishing returns do not prevail.

In section "B" below the traditional specification of the production function will be regarded first. In this section capital and labour are implicitly assumed to be homogeneous. A comparison between the production function in the original theory of the firm and the statistical production function is drawn. Also the problem of estimating the Cobb-Douglas production function is briefly stated. A condensed comparison between the widely known production functions is undertaken. A definition of the variables is presented and a preference for the experimental approach instead of assuming the validity of a given form is emphasised. Then the estimation of the traditional form of production function is presented.

In section "C" a development of a practical method is introduced in order to estimate two broad layers of vintage of capital. It is followed by the result of establishing a distinction between modern and older vintages of capital in the specification of the production function.

B. <u>The Traditional Specification of the Production Function</u>:

(a) The statistical production function:

It is known that the production function in the original theory of the firm describes the technically feasible possibilities facing the entrepreneur at a given point in time. He is supposed to be dealing in a perfect output and inputs markets and producing a homogenous commodity using homogenous qualities of labour and capital. The closest approximate for such a function in practice is an intra-firm (time series) production function. The pioneer attempt to estimate a statistical production function was made by Cobb and Douglas who estimated an intra-industry or time series of manufacturing industries production function. The original form implies the assumptions of constant returns to scale, perfect competition in the product and input markets and unitary elasticity of substitution. Therefore, the original form lacks the ability to test for returns to scale, the degree of competition in the input markets and evaluating the elasticity of substitutions. In the unrestricted form they used in the 1940's, the homogeniety restriction was removed and thus the coefficients of labour and capital were left free to indicate decreasing, constant, and increasing returns to scale.

In his familiar paper "Are there laws of production?", Douglas presented the results of two decades of team effort using mainly cross-sections of inter-industry production functions. Being conscious of the criticisms directed at this method of analysis especially the doubt in the meaningfulness of the estimated coefficients in predicting the level of output which obtains from separate or combined changes in the input factors, Douglas defended this method convincingly.[1] He pointed out that:-

> "This method is somewhat disconcerting to those who are accustomed in their a priori reasoning to start within the theory of production for the individual firm and who then move to a model for a given industry but who shy away from developing a theory of production for the economy as a whole or for the manufacturing sector of that economy. Such theorists probably believe that we are starting at the wrong end and that we should begin instead with the individual firm rather than the whole manufacturing sector of the economy and that we should consider the production function within these units rather than deal with inter-industry and aggregate functions."(2).

---

(1) It is to be noted that in the reply summarised below, it seems that he did not attempt to defend the traditionally specified production function in ignoring the aggregate bias and the reliance of the evaluation of returns to scale on the arbitrariness of industrial classification of official statistics and the possibility that large industries may be composed of a large number of small firms and small industries of large firms. See Section C of Chapter I and Walters 1968, p.311 respectively.

(2) Douglas "Are there laws of production?" A.E.R. Vol. 38, March, 1948, pp. 22-23.

In addition to the major difficulty of obtaining firms' data because of industrial secrecy he emphasised that there is:-

> ". . . . . no reason why we cannot approach this problem from either end and study the macrocosm as well as the microcosm. No/one, in the physical science would propose that we give up using the telescope because the microscope has not yielded all its secrets. Why should we not, therefore, study the economy as a whole as well as speculate about the individual firm, particularly since a knowledge of the former throws a great deal of light upon the problems of the latter."(1)

(b) Problems of estimating the Cobb-Douglas production function.

The problem of the simultaneous equation bias in the estimates of the single equation least squares production function, which arise from the possibility of interdependence of the explanatory variables and the residual was pioneered by Marschak and Andrews (1944). Because of the computational burdens of solving the production system simultaneously simpler and less costly methods were suggested. The method of moments (Marschak and Andrews, 1944), and Hoch method (Hoch 1958) were shown by Kmenta 1963, to be equivalent to the method of indirect least squares. Within this group of methods of estimation to the Cobb-Douglas production function, the assumption of perfect competition can be relaxed and instead it can be subjected to test. This can be done by introducing a multiplicative constant to each one of the marginal productivity equations. If it is found that it is significantly different from one, the hypothesis of perfect competition can thus be rejected.

The task of comparing the properties of the various methods of estimation of production function parameters has been the preoccupation of the Monte-Carlo studies (see Kmenta and Joseph, 1963) and is beyond the scope of this study. The main occupation of this analysis, it is

---

(1) Douglas "Are there laws of production?" A.E.R. Vol. 38, March, 1948 pp. 22-23.

to be recalled, is to reduce the aggregate bias resulting from the erratic specification of the aggregate production function and of the factors of production. It is thus not unrealistic to suggest that the steps taken here to deal with this problem may well preceed the steps necessary to deal with the simultaneous equation bias.

(c) Various forms of production functions;

It is well known that each form of production function is based upon a set of assumptions. Instead of accepting the assumptions of a certain form as given, it is reasonable to regard that amongst a number of functions which are difficult to distinguish between them on priori grounds, which-ever function renders the sharpest parameters, combined with the highest explanatory power is the most likely to represent the population from which the sample has been drawn. A time and effort saving device is to assume a given functional form as suitable for application, but a more scientific approach tends to favour instead what is recommended on empirical grounds amongst equally plausible functions. Therefore, it is to be noted that since the unrestricted production function in its log and absolute forms have proved to be the most acceptable forms for British and Scottish manufacturing industries, the main findings will be given in these two forms. However, the semi-log forms, though not as acceptable, nevertheless have been reported as they indicate that a transcendental form production function may well be superior to the log and absolute forms (see below). Since the latter function involves double the loss of degrees of freedom compared with either the log or absolute forms, its application in the present situation must be limited by the lack of sufficient numbers of observations.

The unrestricted Cobb-Douglas form has unitary elasticity of substitution and constancy of output elasticity with respect to the factors of production. Since it involves no restrictions on output elasticity, its coefficients are left free to reflect constant, decreasing, and increasing returns to scale. Although the constant elasticity of substitution production function has gained a wide fame it has not replaced the Cobb-Douglas production function; partly because it gives rise to non-linear estimation problems and partly because it yields unstable estimates of the elasticity of substitution. As a more general form the former gave room for testing another, though equally plausible, assumption concerning the elasticity of substitution. Both functions take an intermediate position with regard to the assumption concerning the value of the elasticity of substitution. At the two extremes, input/output analysis involves zero elasticity of substitution or fixed input/output ratios, while the linear production function involves the assumption of infinite elasticity of substitution.

(d) Definition of the variables used:-

An inter-industry cross-section production function will be estimated using British and Scottish manufacturing industries data. Output is measured by:-

1. Net output which is defined by the Census of Production as constituting the funds from which wages, salaries, rents, rates, taxes, advertising and all other selling expenses and all other similar charges have to be met. It, therefore, exceeds the familiar concept of value added to the extent that services bought from other industries are not excluded.

2. Gross output is the total value of sales and work done corrected for stock appreciation and depreciation. Labour is measured by numbers in employment. That is the numbers unemployed were subtracted from the number of insured labour. Capital is measured by the net stocks of all fixed assets at 1954 prices. The intermediates is measured by the cost

of materials and fuel purchased (including the value of goods purchased for merchanting and canteen supplies), the amount paid for work given out to other firms and payment for transport.

In order to trace out the consistency of the results, a production function describing gross output is estimated in many cases and the similarity of the conclusions based on either this function or the usual function describing net output will be presented. In specifying the gross output function an additional input factor viz. intermediates is introduced.

It is to be recalled that for British manufacturing industries gross output figures are provided by the Census of Production reports while net output has to be estimated for 1962. Therefore the results of the gross output function may as well be used as a means of evaluating the consistency of the estimates of net output.

Interpretations of the net output functions are given the main consideration on the grounds that net output represents the value added to intermediates by the process of production and thus is the meaningful concept on an industry level. Moreover, in contrast with gross output, it is emphasised by the Board of Trade that there is no appreciable duplication in net output.

Moreover, instead of assuming a given form of production function as suitable for the industrial sector(s), an experimental approach is adopted. However, those forms which show relative inferiority toward the others are given less attention after comparing their performance with the relatively superior ones. For instance in this section a restricted Cobb-Douglas form, a linear form, an unrestricted Cobb-Douglas form, and two semi-log forms are estimated. It will be shown that the first and the last two forms are indicated as inferior relative to the other forms.

(e) The estimates of the traditional production function.

The restricted Cobb-Douglas production function involves the restriction that the sum of the output elasticity with respect to labour and capital is equal to 1. It takes one of the two forms:-

$$\ln(O/K_A) = a_o + a_1 \ln(L/K_A) \tag{6.1}$$

or

$$\ln(O/L) = b_o + b_1 \ln(K_A/L) \tag{6.2}$$

where O, K_A, L refer to output, all fixed assets, and labour respectively. a_1 of (6.1) represents the labour elasticity and the capital elasticity is equal to $(1 - a_1)$. b_1 of (6.2) represents the output elasticity with respect to capital and the labour elasticity is given by $(1 - b_1)$.

The form (6.2) is estimated for British manufacturing industries as:-

$$\ln (NO/L) = 2.434 + \underset{(0.048)}{0.306} \ln (K_A/L) \qquad R^2 = 0.658, \ \bar{R}^2 = 0.642$$

therefore the labour elasticity is 0.694.

The counterpart is estimated for Scottish manufacturing industries as:-

$$\ln (NO/L) = 2.2.97 + \underset{(0.070)}{0.283} \ln (K_A/L) \qquad R^2 = 0.440, \ \bar{R}^2 = 0.413$$

which gives the labour elasticity as 0.717.

The unrestricted Cobb-Douglas in its log form is:-

$$\ln O = a_o + a_1 \ \ln L + a_2 \ln K_A \tag{6.3}$$

The application of (6.3) for British manufacturing and Scottish manufacturing industries is given by (6.1.4) and (6.1.12) of table (6.1) respectively. Table (6.1) records the estimates for other forms as well.

Table (6.1) Cross-section Estimates of the Aggregate Manufacturing

Regression Number	Dependent variable.	Constant Term.	Total Employees Absolute.	Total Employees Log	Net Stock of fixed assets. All. Absolute.	Net Stock of fixed assets. All. Log.
				- British		
1	NO	-42·64	0·874 (0·068)		0·386 (0·053)	
2	lnNO	6·974	0·00212 (0·00039)		0·000807 (0·000230)	
3	NO	-1694·5		208·39 (54·79)		169·99 (48·31)
4	lnNO	2·112		0·733 (0·056)		0·324 (0·049)
5	GO	-32·48	0·806 (0·068)		0·322 (0·055)	
6	lnGO	1·672		0·227 (0·034)		0·139 (0·047)
7	lnG	1·862		0·211 (0·024)		
8	lnNO	2·609		0·710 (0·041)		
				- Scottish		
9	NO	-4·307	0·756 (0·084)		0·412 (0·090)	
10	lnNO	4·353	0·0183 (0·0089)		0·0136 (0·0052)	
11	NO	-58·79		18·124 (6·401)		11·959 (5·872)
12	lnNO	2·189		0·741 (0·080)		0·295 (0·073)
13	GO	-2·622	0·689 (0·074)		0·233 (0·096)	
14	lnGO	5·379	0·0118 (0·0035)		0·0177 (0·0045)	
15	lnGO	1·487		0·205 (0·035)		0·122 (0·046)

(6.1)

Production Function for British and Scottish Industries (1962)

Net Stock of fixed assets Modern Log	Old Log	Materials, Fuel, etc. Absolute	Log	R^2	$\bar{R}^2$
Manufacturing Industries -					
				0·965	0·962
				0·819	0·801
				0·793	0·773
				0·966	0·962
		0·1061 (0·0025)		0·9973	0·9968
			0·624 (0·049)	0·9876	0·9856
0·236 (0·041)	-0·136 (0·048)		0·641 (0·036)	0·9941	0·9928
0·456 (0·069)	-0·175 (0·079)			0·983	0·980
Manufacturing Industries -					
				0·946	0·940
				0·790	0·769
				0·695	0·665
				0·946	0·940
		0·110 (0·003)		0·9969	0·9964
		0·000122 (0·000147)		0·8975	0·8813
			0·663 (0·051)	0·9906	0·9891

The following remarks are interesting from the point of view of the traditional specification of the production function:-

Firstly; In spite of the large difference between the $\bar{R}^2$ of the restricted and unrestricted forms, being for the former 0.642 and 0.440 and for the latter 0.962 and 0.940 for British and Scottish manufacturing industries respectively, the difference between the elasticities estimated by either form is less than one standard error. Instead of assuming that the sum of the labour and capital elasticities equals one, the unrestricted form reveals that the sum of the two elasticities is 1.057 and 1.036 for British and Scottish manufacturing industries respectively. Therefore there is a slight suggestion that the manufacturing industries in the two sectors are operating on the point of increasing returns to scale. However, applying the statistical test reveals that the hypothesis of constant return to scale cannot be rejected.(1) It is to be noted that the concept of returns to scale is difficult to test in an inter-industry situation since the size of industries dpends to a large extent on what the official statistics may regard as suitable industrial classification. Moreover, small industries may be composed of a few large firms and large industries may be composed of small firms (Walters, 1968).

---

(1) Defining the sum of squares of the residuals of the unrestricted form as Q_1 and the sum of squares of the residuals of the restricted form as Q_2, the null hypothesis is that Q_1 is not different from Q2, The test function is:-

$$F = \frac{(Q_2 - Q_1)\ (N - P)}{Q_1} \frown F(1, N - P)$$

Since the calculated F for British and Scottish manufacturing industries are 1.6 and 0.4 respectively then the null hypothesis cannot be rejected.

Comparing the estimates of the restricted and unrestricted forms of production function shows that the latter is superior to the former. More importantly, the consistency between the estimated elasticities of the two forms is a source of satisfaction. Moreover, a comparison between the estimated elasticities of the unrestricted Cobb-Douglas form in its traditional specification with previous studies of inter-industry production functions reveals further the consistency of the above estimates. Broadly speaking the labour elasticity is almost two thirds of the sum of labour and capital elasticities and the capital elasticity accounts for the remaining third.

Secondly: Comparison between the unrestricted Cobb-Douglas form (6.1.4) and the linear form (6.1.1) for British manufacturing industries indicates that the $\bar{R}^2$ is the same reaching 0.962, the labour coefficient is more than 13 times its standard error in both forms and that the capital coefficient is almost 7 times its standard error in the former and more than 7 times its standard error in the latter function.

An almost similar picture can be drawn for the Scottish sector from the comparison between the unrestricted Cobb-Douglas form (6.1.12) and the linear one (6.1.9). The $\bar{R}^2$ is the same and equal to 0.940 and the labour coefficient is more than 9 times the standard error and the capital coefficient is more than 4 times its standard error in both forms.

In the production function explaining gross output for British and Scottish manufacturing industries the findings of the unrestricted Cobb-Douglas form (6.1.7) and (6.1.15) indicate close similarity in the $\bar{R}^2$ and the sharpness of the coefficients when compared with the linear form (6.1.5) and (6.1.13) respectively.

Therefore, it seems difficult to prefer either form from the other merely on statistical grounds. However, the assumptions involved in the unrestricted form are more acceptable on a priori grounds compared with the assumptions involved in the linear form (see above).

Thirdly: Compare the unrestricted Cobb-Douglas and the linear forms with the two semi log forms (6.1.2) and (6.1.3) for British and (6.1.10) and (6.1.11) for Scottish manufacturing industries. The performance of the former two is shown to be superior to the performance of the latter two forms in terms of the $\bar{R}^2$ and the sharpness of the coefficients. The two semi log. forms still give a statistically acceptable fit to the available and estimated data.

The superiority of the unrestricted and linear forms and the yet satisfactory performance of the two semi log forms from the statistical point of view may suggest that a transcendental production function is likely to be acceptable on statistical and economic grounds.(1) The availability of so few observations is the limiting factor in investigating this view empirically.

---

(1) The transcendental production function takes the form:-

$$O = A_o L^{a_1} e^{b_1 L} K^{a_2} e^{b_2 K} T^{a_3} u$$

Taking, e.g. the capital input and equating each one of the first and the second derivatives with respect to K to zero and solving for K gives respectively the maximum output achievable when $K = a_2/b_2$ and the point of inflection when $K = (-a_2^2 + a_2)/b_2$

I - for a value of $b_i < 0$;

(i) if $0 < a_i < 1$ output increases at a decreasing rate until the input factor reaches $- a_i/b_i$ then the output decreases.

(ii) if $a_i > 1$ output increases at an increasing rate until the input factor reaches $(- a_i + \sqrt{a_i}) / b_i$; then it increases at a decreasing rate until the factor reaches $- a_i/b_i$ then it decreases.

II - for a value of $b_i = 0$ which is the case for the Cobb-Douglas form:-

(i) $0 < a_i < 1$;

(ii) $a_i = 1$; and

(iii) $a_i > 1$;

output increases at a decreasing, constant, and increasing rate respectively.

Fourthly: in the production function for British Manufacturing Industries the estimated elasticity of output with respect to employment in the Cobb-Douglas form (6.1.4) is 0.733 and the estimated elasticity with respect to capital is 0.324. These estimates thus indicate that on the average 0.1 per cent change in employment, (capital is kept unchanged), may lead approximately to 0.073 per cent change in output.

Similarly an 0.1 per cent increase in output may be achieved by increasing the stock of capital by just less than 0.3 per cent, (without changing the level of employment).(1)

It is to be noted that this interpretation pertains to the tranditional specification of the production function. It will, however, be seen below (Chapters X and XI) that, e.g., the capital elasticity which is estimated according to the traditional specification is biased.

= III - for $b_i > 0$:

(i) $0 < a_i < 1$

output increases at a decreasing rate until the input factor reaches $(-a_i + \sqrt{a_i})/b_i$ then increases at an increasing rate.

(ii) $a_i > 1$

output increases at an increasing rate

The classical interpretation of the production function is confirmed when b_i is negative and $a_i > 1$; the output first increases at an increasing rate and, after reaching a maximum it decreases as diminish returns apply.

---

(1) It is to be noted that such an interpretation implies that the estimated elasticities represent closely the true parameters of the population.

The bias involved is dominantly caused by aggregation and partly by management bias. The former should be reduced through correcting for the vintage of capital (see section D below), the structure of capital (see Chapter VII), the level of activity (see chapter VIII), the structure of labour (see chapter IX), the scientific effort in research and development (see Chapter X) and the scientific effort on-the-shop-floor (see Chapter XI). Managerial bias should be reduced by using scientific effort in managerial activities as a proxy for managerial input (see Chapter XI).[4]

Bearing in mind that in measuring the variables, less published information was available for Scottish manufacturing industries and estimates were thus used more frequently compared with British manufacturing industries, the output elasticities are 0.741 with respect to labour and 0.295 with respect to capital.[5]

F. <u>Testing the difference between the British and the Scottish estimates.</u>

In his paper, Chow (1960) has been concerned, among other things, with the question of whether the estimated linear relationship holds for two different groups of economic units. In the present situation the explicit question is whether the fitted production function for Scottish manufacturing industries is statistically significant from the one fitted for the manufacturing industries of the United Kingdom as a whole. Before running the required test the following points are worthy of notice.

1. In the strict sense the comparison should be between Scotland and the United Kingdom, net of Scotland. Due to the difference in the nature of the data used for estimating the production functions of the two sectors, an attempt aimed at reducing the output and inputs of the United Kingdom by the estimated Scottish figures is likely to introduce unknown bias in the estimates of the production function of the United Kingdom. Undertaking the comparison between the production function of Scotland and the whole of

the United Kingdom is likely to be suggestive since the Scottish share is in the order of 10% of the United Kingdom.

2. A choice between the estimates of the Cobb-Douglas and linear production functions on statistical grounds seems very difficult since the fit of both functions is very close and satisfactory. However, on priori grounds only the estimates of the former were mainly relied upon in the interpretations of the results. The closeness of the fit of the two forms is particularly useful since the available tests of equality between sets of coefficients in two regressions are designed for linear functions. Therefore, the test here is applied on the estimates of the linear production functions. The results thus obtained are likely to be in agreement with the results of comparing the Cobb-Douglas estimates.

3. The net output figures are in current value for the United Kingdom while they are at 1958 prices for Scottish manufacturing industries.

The Chow test for the whole relationship for two economic units when the number of observations in either exceeds the number of the coefficients is equivalent to the standard covariance test. The null hypothesis is that the coefficients of the linear production function of the United Kingdom manufacturing industries are not different from the coefficients of its Scottish counterpart. In other words, if the null hypothesis is not rejected the Scottish manufacturing industris are considered as belonging to the same population of which the British manufacturing industries are drawn.

Let Q_1 be the sum of squares of the residuals under the null hypothesis, i.e., those estimated by the production function whose observations are composed of the 46 industries of the United Kingdom and Scotland.

Let Q_2 be the sum of squares of the residuals obtained from the two separate production functions of the United Kingdom and Scotland respectively. define $Q_3 = Q_1 - Q_2$ and $n_1 = 23$ is the number of the United Kingdom observations $n_2 = 23$ is the number of Scottish observations.

$p = 3$ is the number of the coefficients of the net output function.

The statistic $\dfrac{Q_3 / p}{Q_2 (n_1 + n_2 - 2p)} \frown F\ (p, n_1 + n_2 - 2p)$

The calculated $F = \dfrac{7285.06/3}{86096.60/40}$

$= \dfrac{2428.35}{2152.41}$

$= 1.12$

On the basis of this evidence the null hypothesis cannot be rejected.

C: The Vintage of Capital:

(a) Theory:

The aggregate production function as given by equation (6.3) needs either to be adapted or developed in order to suit the improvements sought by the present study. Let the quality of capital, as reflected by the vintage aspect, be considered first. One method of dealing with the vintage of capital in practice is to introduce a simple modification to equation (6.3) and to reformulate it as follows:-

$$O^* = f(L^*, K^*, A^*) \tag{6.4}$$

Equation (6.4) may be regarded as a vintage production function in which K^* is the quantity of recently purchased capital, L^* the labour operating it, and O^* the output produced from it. A^* thus measures the best practice technological efficiency that may be achieved through the use of some representative assortment of the most modern capital assets. Equation (6.3) on the other hand measures the average level of technical efficiency achieved in practice by using all vintage of capital, old and new in a firm, industry, or the whole economy.

The application of equation (6.4) is suitable for inter-plant, inter-firm and inter-regional etc., functions. It is applicable, for instance, to a set of firms that started production in recent years as newcomers, (rather than taking over pre-existing ones), in a given industry. Alternatively it may be applied for new plants (whether belonging to newly established firms or older ones).

In practice, however, the data needed to apply equation (6.4) is difficult to obtain. Moreover, a direct method which aims at comparing the performance of the modern and older stocks of capital is needed. One way of doing this is to regard the accumulated capital formation during a recent period (say the last seven years) as new capital and thus the rest of the stock of capital as old. The concept of gross investment rather than net investment is the most relevant.(1)

This approach divides capital into only two main vintages of capital (in order to cope with the available few number of observations, there being nothing else to prevent finer breakdown), old and new. Thus each vintage is treated as a different type of capital in the following form:-

$$O = f(L, K_n, K_r, A) \qquad (6.5)$$

where K_n stands for new capital and K_r stands for old capital, (other variables are defined as before).

K_n is measured by accumulated gross investment over the preceeding seven years minus the depreciation of capital assets bought during that period. Defining the accumulated gross investment net of capital consumption in a discontinuous situation as:-

$$K_n = \sum_{t = T - 6}^{T} I(t)(1-\delta)^{T - t + 1} \qquad (6.6)$$

where I refers to gross Investment at the time period "t" and δ stands as a deterioration rate.

In a continuous function (6.3) may be formulated as:-

$$K_n = \int_{t = T - 7}^{T} I(t) \quad e^{-\delta(T - t)} \quad dt \qquad (6.6.)1$$

If an amount $I(t)^{dt}$ of gross investment is installed in the time interval (t - dt, t) then an amount $\int_{t = T}^{T + 1} I(t) \quad e^{-\delta(T - t)}$ dt of this gross investment will still be active at time t + dt (dt > o).

δ is introduced to render K_n commensurate with the assumption that the net stock concept is more realistic as far as the productive capacity is concerned. The seven years period is an arbitary period but the length of the shortest lived asset, namely, vehicles, is almost seven

---

(1) The difference between gross investment and net investment is capital retirement or scrappage and the distinction is essential in growth models which advocate keeping capital intact in order to preserve "at least" the productive capacity of the economy from declining through negativenet investment.

years and thus the problem of scrapage of the new type of capital is avoided. Obviously (6.6) may not be considered as ideal since a further breakdown by type of asset must be introduced (See chapter VII).(1)

---

(1) It is to be noted that estimating the modern vintages of capital according to (6.6) disregards the fact that the stock of fixed assets is composed of different types of assets whose assumed life-span varies considerably, e.g., the average life of industrial buildings is assumed by Cambridge estimates to be equal to 50 years, while the average life of vehicles is assumed to be 7 years only. It follows that the direct application of (6.6) can be achieved by assuming an average life for the overall fixed assets which is arbitary and less satisfactory in an inter-industry study.

The steps followed in estimating (6.6) are as follows:-

1. The gross investment of each one of three fixed assets, viz, plant and machinery, industrial buildings, and vehicles for the recent seven years (1956 - 1962) was deflated by the appropriate price index to estimate the constant prices gross investment.

2. The (constant (1954) prices) gross investment of each type of asset was depreciated according to an assumed life span (given by Cambridge) as follows:-

    1. A 50 years life span for industrial buildings.

    2. A 7 years life span for vehicles.

    3. A life span for plant and machinery which is allowed to vary from industry to industry which can be averaged roughly round 25 years.

K_r on the other hand refers to the capital stocks with vintage of more than seven years, not of scrapage and depreciation. The perpetual inventory approach is now reformulated to measure old capital as follows:-

$$K_r = \sum_{t = T - \theta}^{T-7} I(t) \; (1 - \delta)^{T - t + 1} \qquad (6.7)$$

The retirement of old assets is now being taken care of by O which is the length of life of the asset and the summation is taken over the life span of the capital assets. The estimates of modern and older vintages of capital according to (6.6) and (6.7) are included in table (4.27) above, (See Chapter IV).

The use of the estimates of K_n and K_r in order to estimate equation (6.5) implies that the two types of vintage capital are weighted, according to the resources allocated to their instalment minus the value of the physical deterioration and retirement. However, the qualitative difference as well as the age effect should be reflected in a decisive difference in their ability to contribute to the productive process.

Unfortunately equation (6.5) cannot be applied to the available data on capital formation for Scottish manufacturing industries since apart from 1958 (the main census) there is no year to year data for which the breakdown of capital formation by industry is given. However, an application to the British manufacturing industries alone is possible as well as informative.

(b) Application:

Equation (6.5) is estimated by (6.1.8) which indicates that:-

1. The output elasticity with respect to modern plant and machinery is 6.6 times its standard error. The contribution of the modern stock of capital to the production process is 40.7 per cent more than the contribution of the average age stock of capital.

This finding is thus consistent with the Johansen thesis which suggests that modern vintages of capital are better than older layers since they are supposed to incorporate the most up-to-date technological advance.

2. The output elasticity with respect to older vintages of capital is negative and statistically significant at the 5 per cent level. This finding is consistent with the mainly empirical view which is in line with some industrialists view that the older vintages of capital represents a handicap to industrial growth and efficiency.

3. The output elasticity with respect to labour is slightly lower than in the traditional production function (6.1.4) but the degree of sharpness is increased considerably. The labour coefficient is now 17.3 times its standard error as compared with 13.1 times in the traditional specification.

4. The introduction of the distinction between modern and older vintages of capital allowed 47 per cent of the residual to be explained. This finding is generally consistent with the finding of M. Panic.(1) Though he dealt with a time series situation in his attempt to explain the difference between the rates of growth in West Germany and the U.K.

---

(1) M. Panic "Gross Fixed Capital Formation and Economic Growth in the U.K. and West Germany 1954 - 1964". B O I E S. Nov. 1967.

Panic found that about 42 per cent of the growth of output can be accounted for by the differences in gross investment to G N P ratios. In other words that the stock of capital in Germany is modernized at a rate faster than the U.K. was indicated an influential factor in the faster growth of the former's output vis - à - vis the latter's.

The tentative conclusions which can be suggested by the above stated findings are:-

(i) that a serious bias is likely to be involved in assessing the technical efficiency and/or the coefficients of the production function if no distinction is drawn between various layers of vintage of capital.

(ii) that if capital formation is allowed to accumulate at a higher rate such as to alter the balance in favour of modern capital, then a considerable increase in the average efficiency of capital is likely to occur. Moreover, the increase in the degree of capital modernization is likely to be most favourable for the industrial growth and technical efficiency.(1)

(iii) that in forecasting full employment output for future date, a measurement of capital that ignores a distinction between modern and older vintages of capital is likely to result in underestimating the potential output if capital formation proceeds at a rate faster than the one experienced during the period used in forecasting and vice-versa.

---

(1) It is to be noted that the findings support qualitative increase rather than quantitative increase of capital.

CAPTER VII

THE MEASUREMENT OF CAPITAL
II-THE STRUCTURE OF CAPITAL

THE MEASUREMENT OF CAPITAL

II The Structure of Capital

In most empirical work, capital goods are aggregated in one figure as if they perform similar functions. The lack of substitutes is the main justification. This remains so even if a distinction between various layers of capital vintage is introduced. Our model embodies a greater degree of disaggregation, on the grounds that both different types of capital and different vintages make different contributions to the productive process. However, the question of capital homogeneity cannot be pursued to the extent of establishing a distinction between each vintage of each type of capital structure on practical as well as on theoretical grounds. On practical grounds the number of observations required will be enormous, unless the study is reduced to a given vintage or a given type of capital structure. On theoretical grounds the attempt to pursue the homogeneity requirements to a large extent is likely to bypass the inter-action between various layers of vintages as well as between various structures of capital.

A balanced approach is to consider the distinction between a small number of capital structures as well as a limited number of capital vintages. In the present study this view is necessitated by the restricted number of degrees of freedom available. In Section A, the structure of capital is discussed. In Section B, the combination of the structure and the vintage of capital is considered.

A. The structure of Capital:

On an industry level, three types of capital can be distinguished. These are plant and machinery, new buildings, and vehicles. Thus an improvement over the usual aggregate production function is to use the form:-

$$O = f(L, K_p, K_b, K_v, A) \tag{7.1}$$

where the three subscripts to capital refer to the three types of capital respectively. It is also obvious that (7.1) does not allow for the quality of capital. A greater improvement is thus possible by:-

$$O = f(L, K_{np}, K_{nb}, K_{nv}, K_{rp}, K_{rb}, K_{rv}, A) \tag{7.2}$$

where the first subscripts of K refer to two vintages of capital, "n" new and "r" old, and where the second subscript in each case refers to the three types of capital.

The difficulty with applying equation (7.2) to our situation is not only due to the consumption of an already small number of degrees of freedom, but also to the multi-colinearity involved.

Due to the finding that equation (7.1) was also difficult to apply because of multicolinearity, a more modest equation is:-

$$O = f(L, K_p, K_o, A) \tag{7.3}$$

where K_o represents structures of capital other than plant and machinery. Equation (7.3) draws a distinction only between plant and machinery and all other infra-structures. The assessment of equation (7.3) using the Cobb-Douglas production function for British and Scottish manufacturing industries is given by equations 6 and 18 of Table (7.1).

Moreover Table (7.2) provides a concise inter-regional comparison of the most interesting results as follows:-

Table (7.1) Cross section estimates of the aggregate

Eqn. No.	Dependent	Constant	Coefficient				
			Labour		Plant & Machinery		
						All.	Modern
			Absolute	Log	Absolute	Log.	Log.
					-British Manufacturing		
1	NO	-41·538	0·952 (0·072)		0·476 (0·079)		
2	lnNO	6·975	0·00228 (0·00036)		0·00101 (0·00040)		
3	NO	-1601·6		231·99 (51·96)		142·27 (41·96)	
4	lnNO	2·283		0·774 (0·052)		0·277 (0·042)	
5	NO	-41·01	0·779 (0·075)		0·180 (0·105)		
6	lnNO	2·324		0·744 (0·070)		0·227 (0·088)	
7	GO	-29·014	0·835 (0·70)		0·387 (0·072)		
8	lnGO	7·997	0·00136 (0·00034)		0·00106 (0·00035)		
9	lGO	1·708		0·242 (0·033)		0·114 (0·038)	
10	GO	-35·123	0·777 (0·075)		0·231 (0·113)		
11	lnGO	1·754		0·231 (0·041)		0·0968 (0·0540)	
12	lnNO	2·607		0·757 (0·048)			0·354 (0·088)
13	lnNO	2·630		0·773 (0·056)			0·322 (0·102)
14	lnNO	2·548		0·759 (0·048)			0·270 (0·036)
						- Scottish	
15	NO	-4·167	0·835 (0·079)		0·501 (0·126)		
16	ln	2·319		0·776 (0·072)		0·258 (0·062)	
17	NO	-4·159	0·663 (0·106)		0·198 (0·178)		

production function (1962) (7.1)

of Other capital structures All. Absolute	Log.	All capital excluding plant&machy. Log	Older plant& machiny. Log	Intermediate Absolute	Log.	R^2	$\overline{R}^2$
Industries-							
						0·954	0·949
						0·814	0·795
						0·787	0·766
						0·966	0·963
0·999 (0·281)						0·972	0·968
	0·083 (0·127)					0·967	0·961
				0·1082 (0·0026)		0·9969	0·9965
				0·0000333 (0·0000126)		0·8731	0·8531
					0·634 (0·046)	0·9877	0·9858
0·683 (0·392)				0·10395 (0·0034)		0·9974	0·9968
	0·0354 (0·0791)				0·626 (0·050)	0·9878	0·9851
			-0·103 (0·099)			0·973	0·969
		-0·0776 (0·1430)				0·972	0·968
						0·972	0·969
Manufacturing Industries -							
						0·938	0·931
						0·951	0·943
1·056 (0·473)						0·951	0·943

[Contd.

Table (7.1) (contd.)

Eqn. No.	Dependent	Constant	Coefficient: Labour Absolute	Labour Log	Plant & Machinery All. Absolute	Plant & Machinery All. Log	Plant & Machinery Modern Log
					Scottish Manufacturing		
18	lnNO	2·346		0·762 (0·098)		0·233 (0·127)	
19	GO	-2·515	0·709 (0·070)		0·290 (0·112)		
20	lnGO	-1·546		0·221 (0·034)		0·107 (0·038)	
21	GO	-20·885	0·757 (0·097)		0·376 (0·165)		
22	lnGO	1·558		0·216 (0·043)		0·0990 (0·0580)	

Table (7.1) (cOntd)

of Other capital structures All. Absolute	Log	All capital exc. Plant & Machinery New Log	Old Log	Inter-mediate Absolute	Log	R^2	$\bar{R}^2$
Industries (Contd.)							
	-0·0407 (0·1786)					0·948	0·939
				0·111 (0·003)		0·9970	0·9965
				0·661 (0·049)	0·661 (0·049)	0·9908	0·9894
-0·492 (0·684)				0·113 (0·005)		0·9971	0·9944
	0·0142 (0·0729)				0·660 (0·051)	0·9909	0·9888

TABLE (7.2)

Equation No		Elasticity of Output with respect to						R^2		$\bar{R}^2$	
		All Fixed Assets		Plant and Machinery		Infra Structures					
B	S	B	S	B	S	B	S	B	S	B	S
		Section A:	Net Output as dependent								
6.1.4	6.1.12	0.324 (0.049)	0.295 (0.073)					0.966	0.946	0.962	0.940
7.1.6	7.1.18			0.227 (0.088)	0.233 (0.127)	0.083 (0.127)	-0.041 (0.179)	0.967	0.948	0.961	0.939
7.1.4	7.1.16			0.277 (0.042)	0.258 (0.052)			0.966	0.951	0.963	0.943
		Section B:	Gross Output as dependent								
6.1.6	6.1.15	0.139 (0.047)	0.122 (0.046)					0.9876	0.9906	0.9856	0.9891
7.1.11	7.1.22			0.0968 (0.0540)	0.0990 (0.0580)	0.0354 (0.0791)	0.0142 (0.0729)	0.9878	0.9909	0.9851	0.9888
7.1.9	7.1.20			0.114 (0.038)	0.107 (0.038)			0.9877	0.9908	0.9858	0.9896

B. Refers to British Manufacturing Industries
S. Refers to Scottish Manufacturing Industries

The following remarks may be drawn from Table (7.2):-

Firstly: It is clear from the second and fifth lines that the coefficient of plant and machinery is dominant while the coefficient of infra structures is not significant for British and Scottish manufacturing industries, whether in the net or gross output function. All the four equations are affected by multicollinearity. Yet with the exception of (7.1.18), the other equations indicate that the sum of the elasticities of plant and machinery and infra structures are close to the estimated elasticities of all fixed assets given by the corresponding three equations (6.1.4), (6.1.6) and (6.1.15). This means that the estimated elasticities of capital structure are not badly affected by multicullinearity.

Secondly: Comparing the output elasticity with respect to plant and machinery and other infra-structures reveals that for British and Scottish manufacturing industries the elasticity of plant and machinery is several times larger than the corresponding infra-structure elasticity. This finding implies:-

1. that a measurement of capital which ignores a distinction between various types of capital involves a mistaken specification that is likely to result in an overstatement of the level of the estimated technical efficiency (See Section "B" of Chapter V).
2. that a planned full employment level of output for a future date which is based on extraprolating capital requirements ignoring the structure of capital, is likely to be understated if the rate of forming plant and machinery overtakes the rate of accumulating other types of capital.

Thirdly: The lesser capacity to contribute, combined with the lower level of significance of the infra-structure coefficient is noteworthy. From a statistical measurement point of view, the ability of the plant and machinery variable to be representative of the capital factor is demonstrated by the estimates (7.1.4), (7.1.9) for British and (7.1.16) and (7.1.20) for the Scottish Manufacturing Industries which excludes the infra-structure variable. The explanatory power of these production functions exceeded $\bar{R}^2$ in the corresponding estimates (6.1.4), (6.1.6), (6.1.12) and (6.1.15) respectively which measures capital by the stock of all fixed assets. It thus seems likely that the explanatory power of of capital as a whole is derived mainly from the plant and machinery component. Therefore, it may be reasonable to advance the view that even in the absence of significance of other types of capital, plant and machinery is by and large a better representative of the contribution of capital to output than is total capital.

B. Combining the structural and qualitative aspects of capital:

The form which has to be decided upon as suitable, in view of the previous experimentations, must consume as few degrees of freedom as possible. The production function used may take either the form:-

$$O = f(L, K_{np}, K_{A-np}, A) \tag{7.4}$$

or

$$O = f(L, K_{np}, K_{rp}, A) \tag{7.5}$$

where K_{np} refers to the modern types of plant and machinery. It is measured by the accumulated gross investment net of deterioration in plant and machinery in a manner similar to calculating modern types of all fixed assets. The equation used for this purpose is:-

$$K_{pn} = \int_{T-7}^{T} I_p(t) \quad e^{-\delta p(T - t)} \quad dt \tag{7.6}$$

where $I_p(t)$ refers to gross investment in plant and machinery at the "t^{th}" time period and δp is the rate of deterioration of plant and machinery. In a discrete situation (7.6) may be reformulated as:-

$$K_{pn} = \sum_{t = T - 6}^{T} I_p(t) \quad (1 - \delta_p)^{T + 1 - t} \tag{7.7}$$

K_{rp} in equation (7.5) represents all remaining stock of plant and machinery with a vintage more than seven years. It may be estimated by an equation similar to (7.7) or simply as the difference between the total stock of plant and machinery and the modern stock, i.e.

$$K_{pr} = K_p - K_{pn} \tag{7.8}$$

K_{A-np} stands for all assets excluding modern plant and machinery. It can simply be estimated as:-

$$K_{A-pn} = K_A - K_{pn} \tag{7.9}$$

Using the British statistics the estimation of the production function as formulated by (7.5) in its Cobb-Douglas form is given by (7.1.12). Equation (7.1.12) indicates that the elasticity of modern plant and machinery is dominant and most significant as compared with the elasticity of older plant and machinery. In contrast with the greater contribution of modern plant and machinery (relative to all vintages, see below) the contribution of older plant and machinery is negative and significant at the 30 per cent level. This finding may be regarded as a further support to the significant finding of Chapter VI which is in agreement with the mainly empirical view that older capital represents a major handicap for industrial growth and efficiency though the significance of the coefficient of older vintage of plant and machinery is low. However, removing the older vintage (7.1.14) helped to improve the fit.

Comparing equations (7.1.4) and (7.1.12) both of which measure capital by the most productive type namely plant and machinery although the former ignores the vintage aspect while the latter corrects for the vintage of plant and machinery, indicates that:-

(a) the elasticity of modern plant and machinery is on the average 27.8 per cent higher than the elasticity of the average age plant and machinery

(b) allowing for the vintage of capital provides an explanation amounting to 16.2 per cent of the residual.

The estimation of (7.4) is given by (7.1.13). It indicates that the output elasticity with respect to modern plant and machinery is again the dominant and most significant when compared with the output elasticity with respect to all other layers of vintages and types of capital. In addition the latter has a negative sign and is not significant.

Comparing equations (7.1.6) with (7.1.13), both of which distinguish between plant and machinery and other structures of capital, but the former ignores the distinction between various layers of vintages and the latter distinguishes between modern plant and equipment and the rest of capital (i.e. older plant and machinery plus all layers of vintage of other structures of capital) indicates that:-

(a) the elasticity of modern plant and machinery is on the average 41.9 per cent higher than the elasticity of average age plant and machinery when capital is represented by all types and vintages of fixed assets.

(b) allowing for the vintage in addition to the structure of capital provides an explanation amounting to 20 per cent of the residual.

What is most important is that the improvement of the specification of capital through considering both the structural and qualitative aspects has further policy implications. The combined conclusion is that it is not only rewarding to rely less and less on old capital but it is also beneficial to relate modernization more and more to plant and machinery in particular, and hence less to infra-structure capital. The force of the argument calling for the acquisition of most up-to-date plant and machinery, and thus scrapping most of the outdated ones, in response to technological change and the challenge of world competition seems to be less convincing if it is applied to buildings and other fixed structures unless such modernization is a prerequisite for introducing newer plant and machinery.

CHAPTER VIII

THE DEGREE OF CAPACITY UTILIZATION

The Degree of Capacity Utilization.

A. Introduction.

Ignoring the level of activity in the specification of the production function is considered here as an omission error for which a correction should be made. A correction for the degree ofcapacity utilization is often made with respect to capital and in time series studies. The presumption is that the efficiency of capital only is likely to suffer from under or unutilized capacity. The view considered here is that the technical efficiency resulting from all factors of production, is likely to suffer from under-utilization of capacity. Moreover, the hypothesis that all productive units in a cross-section study have fully adjusted their level of activity to the phase of the trade cycle prevailing at the studied year is worthy of testing. In addition to the benefit of reducing the likely bias in the estimated technical efficiency, correcting for the degree of capacity utilization is likely to result in reducing the bias imparted in the estimated input-output elasticities via using a stock concept instead of using a flow of services concept in measuring input factors.

In Section B a brief account of the widely applied methods of correcting for the degree ofcapacity utilization and an appraisal of the measurement adopted by the present study is presented. Section C reports the results of application on British and Scottish manufacturing industries and the results of simultaneous improvement with respect to British manufacturing industries.

B. The measurement of the degree of capacity utilization.

Several estimates for the degree of capacity utilization are used in practice. There is little evidence that any of them is preferable to the others. It is important to note that those measures which use the ration of actual output to the potential output raises the possibility of spurious correlation. Yet while this deficiency is recognized, such measures are still used in practice in lieu of an acceptable alternative.

Solow (1957), used the percentage of total labour force employed in order to transform the measured capital stock to flow of services. In this study the ratio of the numbers employed to total labour force is used to measure the degree ofcapacity utilization. However, this ratio is introduced separately in the specification of the production function despite its limitations (see below).

Klein (1954), did adjust for the degree of capacity utilization in his study of cross-section of railways. This he did by using the number of train hours as a measure of the input of capital services.

Massell (1960) uses a minimum capital-output ratio as a capacity benchmark, and then specifies the ratio of benchmark minimum capital-output ratio to each annual capital-output ratio as the measure of utilization.

The Wharton School measure involves drawing trend lines through output peaks to represent potential output series; the ratio of the actual to potential output forms the measure of capacity utilization.

Klein and Preston (1967) advanced that some cyclical peaks may represent weak recoveries and therefore, the Wharton Index may underestimate capacity trends. They thus estimated Cobb-Douglas production functions in terms of man-hour inputs and utilized capital stocks. Define full capacity output as time-series of points on the production surface corresponding to full employment inputs of labour force and total capital stocks. They derived alternative measures of capacity utilization as the ratio of actual output to the estimated potential output.

Amongst the many measures suggested for the degree of capacity utilization, the most handy one to use, given the data available, is the ratio of employees in employment to insured labour.

For the purpose of correcting for the degree of capacity utilization the production function is thus formulated as -

$$O = f(L, K, C, A) \qquad (8.1)$$

where C stands for degree of capacity utilization and all other variables are defined as before.

3. Allowing for both the degree of capacity utilization as well as the structural aspect of capital as follows:-

$$O = f(L, K_p, K_o, C, A) \quad (8.2)$$

where K_p is defined as the stock of plant and machinery and K_o refers to all other infra structures.

The estimation of the linear and Cobb-Douglas forms of (8.1) are given by equations (8.1.1) and (8.1.2). The Cobb-Douglas form for (8.2) is provided by equation (8.1.3) in the same table for British manufacturing industries. The counterparts of these estimates for Scottish manufacturing industries in the same order are given by equations (8.1.10) - (8.1.12).

The following remarks are relevant in interpreting the results obtained.

1. The labour input is measured by the number of employees in employment. It is obvious that this accounts partly for the degree of unemployment in the labour factor since by definition it excludes the numbers already unemployed. A refinement in adjusting labour for the degree of capacity utilization would be to take into account the average hours worked.

2. The capital input is measured by capital stocks rather than by the flow of services, e.g. capital is measured either by the netstock of all fixed assets (equation (8.1)) or the net stock of plant and machinery and the net stock of infra-structure capital (equation (8.2)). One way of rendering the measurement of capital commensurate with the measurement of labour is to correct for the degree of capacity utilization.[1]

---

(1) It is to be noted that present data available on the industry level does not provide information either on idle or on underutilized capital equipment without which a complete agreement between labour and capital measurements may not be possible.

3. The ratio of employees in employment to insured labour taken to approximate the degree of capacity utilization may not respond to such factor as:-

(a) The adjustment of the productive capacity to a lower level within some industries; it is likely that some firms, plants and/or equipment may have been withdrawn from business permanently. If such an adjustment took place, the ratio of unemployed to total labour would be a poor measurement of under-utilization of capital. Moreover, the procedure followed in measuring the stock of capital, (the Cambridge estimates), does not respond for such an adjustment.(1) However, the process of adjustment may be traced through analysing the unemployment statistics for a reasonable number of successive time periods in order to deduce whether or not there has been chronic unemployment.

(b) In view of the lesser accuracy of the breakdown of unemployment figures on an industry basis, it may be doubted whether such a breakdown can be regarded as representing the true distribution. The main reason is that in practice unemployed personnel can be re-employed by other industries in general.

It follows that the ratio of unemployment to total labour may not be regarded as an accurate indication of the extent to which capacity in each industry is proportionately under-utilized. Furthermore, such a ratio may not be an accurate representation of the percentage of excess capacity laid down temporarily by each industry.

---

(1) The retirement of an asset on an industry level is allowed after it has completed an assumed life span.

(c) The possibility of a high elasticity of substitution between numbers and hours worked in an under-employment situation may suggest the limitations of relying on just employment figures in measuring the degree of capacity utilization. Probably a measure that includes the intensity of labour utilization would be more appropriate.

C. Application:

(a) British Manufacturing Industries:

Table (8.1) provides the results of improving the specification of the production function through correcting for the level of activity:-

The general conclusions which can be derived from the estimates of the top section of table (8.1) for British manufacturing industries are:-

1. It seems highly unlikely that the British industries did adjust themselves to the prevailing phase of the trade cycle in 1962. This is suggested by the significance of the coefficient of the degree of capacity utilization at the 1 per cent level whether the production function explains net output or gross output. It is interesting to note that the significance of the coefficient of the degree of capacity utilization is left unaffected when corrections are made for the structure of capital, for the vintage of capital or for a combination of both.

2. The significance of the coefficient of the degree of capacity utilization is not affected by the form of the production function used. For instance in both the linear and the Cobb-Douglas forms which explain net output ((8.1.1) and (8.1.2)) while disregarding the structure of capital, the coefficient of the degree of capacity utilization is significant at the 1 per cent level. In the corresponding equations which explain gross output (8.1.5) and (8.1.6) a similar level of significance is achieved.

3. The introduction of the level of activity in the specification of the aggregate production function allowed on the average 30 per cent of

Table (8.1) Estimates for the aggregate production function

	Dependent	Constant	Insured Labour	Total numbers in Employment		Fixed Assets			
						ALL		MODERN	OLD
			Log.	Abst.	Log.	Abst.	Log.	Log.	Log.
- British Manufacturing Industries -									
1	NO	3051.2		0.843 (0.060)		0.395 (0.046)			
2	lnNO	2.327			0.718 (0.046)		0.328 (0.040)		
3	NO	3078.7		0.922 (0.067)					
4	lnNO	2.493			0.761 (0.044)				
5	GO	-3033		0.775 (0.057)		0.332 (0.045)			
6	lnGO	1.828			0.221 (0.029)		0.150 (0.040)		
7	GO	-3077		0.804 (0.060)					
8	lnGO	1.851			0.238 (0.029)				
9	lnNO	2.101	0.732 (0.058)				0.325 (0.051)		
10	lnNO	2.112			0.733 (0.056)		0.324 (0.049)		
11	lnNO	2.327	0.718 (0.046)				0.328 (0.040)		
12	lnNO	2.728			0.702 (0.033)			0.411 (0.057)	-0.120 (0.065)
13	lnNO	2.646			0.701 (0.035)			0.318 (0.028)	
14	lnNO	2.747			0.751 (0.047)				
15	lnNO	2.742			0.750 (0.040)				
- Scottish Manufacturing Industries -									
16	lnNO	2.399			0.734 (0.077)		0.305 (0.070)		
17	lnNO	2.324			0.770 (0.069)				
18	lnGO	1.530			0.199 (0.033)		0.115 (0.044)		
19	lnGO	1.590			0.213 (0.032)				

which is corrected for the level of activity Table (8.1)

- Coefficients of									
Plant and Machinery				Degree of Capacity Utilization		Raw materials and intermediate.		R^2	$\bar{R}^2$
ALL		MODERN	OLD						
Abst.	Log.	Log.	Log.	Abst.	Log.	Abst.	Log.		
- British Manufacturing Industries -									
				3070.9 (1133.1)				0.975	0.971
					8.443 (2.518)			0.979	0.975
0.490 (0.072)				3100.0 1359.8				0.964	0.958
	0.279 (0.035)				8.124 2.565			0.978	0.974
				3063 (968)		0.1060 (0.0021)		0.9982	0.9978
					4.366 (1.568)		0.611 (0.043)	0.9913	0.9894
0.402 (0.061)				3111 (1043)		0.1082 (0.0022)		0.9980	0.9975
	0.120 (0.033)				4,176 (1,581)		0.625 (0.041)	0.9911	0.9892
								0.964	0.960
								0.966	0.962
					9.161 (2.514)			0.979	0.975
					6.361 (1.875)			0.989	0.987
					7.220 (1.926)			0.987	0.985
		0.272 (0.087)	-0.0056 (0.1215)		7.426 (2.427)			0.982	0.978
		0.269 (0.030)			7.448 (2.318)			0.982	0.979
- Scottish Manufacturing Industries -									
					7.204 (4.352)			0.952	0.945
	0.267 (0.059)				7.322 (4.267)			0.954	0.947
					3.143 (1.779)		0.678 (0.049)	0.9920	0.9902
	0.103 (0.036)						0.676 (0.047)	0.9923	0.9906

the residual of the traditional specification of production function to be explained (see section C).

4. The output elasticity with respect to the degree of capacity utilization is on the average greater than six times the sum of the two elasticities of labour and capital, in particular, at the level of activity prevailing in 1962.

It is, however, unlikely that such a high elasticity will be estimated at other levels of activity. It is likely that the ratio used to measure the level of activity here is partly responsible for reflecting such a high degree of output response to the level of activity.

Moreover, it may be that the variable used to measure the degree of capacity utilization stands as a catch-all for other influential factors which are not allowed for such as the scale of operation. It is known that labour productivity is strongly affected by the degree of capacity utilization. What the present evidence suggests is that technical efficiency is likely to be influenced to a large extent by the level of activity.

5. The reflected considerable response of the flow of output to the degree of capacity utilization seems to suggest profound policy implications. Broadly speaking the supply side seems to require more consideration than is being given at present in managing the economy.

6. The introduction of the degree of capacity utilization does not only increase the explanatory power of the production function but also leads to an improvement in the sharpness of the coefficients of labour and capital. In short it may be regarded as essential to improving the specification of the aggregate production function.

(b) Scottish Manufacturing Industries:

The last section of table (8.1) provides estimates of the production function corrected for the level of activity for Scottish manufacturing industries net output and gross output. They indicate that:-

1. The estimated output elasticity with respect to the level of activity is close to that estimated for British manufacturing industries. This may be regarded as a sign of the consistency of the data estimates for Scottish manufacturing industries. It is to be noted, however, that the significance of the coefficient of the degree of capacity utilization is achieved only at the 10 per cent level.

2. In spite of the low significance of the coefficient of the degree of capacity utilization, a correction for the level of activity allowed on the average for an 8 per cent and 7 per cent explanation of the residual. Compare equation (8.1.16) with (6.1.12) and equation (8.1.17) with (7.1.17). Moreover, the sharpness of the labour and capital coefficients has improved due to correcting for the level of activity.

It is likely that the ratio used for measuring the degree of capacity utilization becomes less representative of the actual capacity utilization when applied to Scottish manufacturing industries than in the case for British manufacturing industries because of the process of adjustment which may be suggested by the clear indication of chronic unemployment in the majority of Scottish manufacturing industries over the 13 months preceeding June of the year of investigation in 1962. The available figures on unemployment are not continuous on a monthly basis. These figures and a simple calculation of the changes in unemployment and the range over six months and 13 months are given in table (8.2) they indicate the existence of chronic unemployment. This finding implies that it is likely that some of the Scottish manufacturing industries have proceeded some of the way towards adjusting their productive capacity, though the adjustment may have not been completed.

TABLE (8.2).

UNEMPLOYMENT IN SCOTTISH MANUFACTURING INDUSTRIES. (June 1961 to June 1962).

	1961.							1962.						6 Months' Range Dec. to June.		A Year Range.	
	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mrch.	Aprl.	May.	June.	Max.	Min.	Max.	Min.
Food, Drink & Tobacco.	2.4	2.3	2.5	2.7			2.9	3.5	3.6				2.9	3.6	2.9	3.6	2.3
Chemicals.	1.0	1.0	1.0	1.0			1.1	1.2	1.1				1.1	1.2	1.1	1.2	1.0
Metals.	2.2	1.6	2.7	2.9			3.3	4.4	5.5				3.1	5.5	3.1	5.5	1.6
Engineering & Electrical Goods.	2.8	2.6	3.0	3.0			3.0	3.4	3.3				4.0	4.0	3.0	4.0	2.6
Ship Bldg. and Marine Engineering.	2.9	2.8	2.6	2.6			3.3	3.3	3.1	N.A.	N.A.	N.A.	3.5	3.5	3.1	3.5	2.6
Vehicles.	0.5	0.5	0.5	0.4	N.A.	N.A.	0.5	0.5	0.5				1.0	1.0	0.5	1.0	0.4
Metal Goods, N.E.S.	0.6	0.6	0.6	0.7			0.8	0.9	0.9				0.9	0.9	0.8	0.9	0.6
Textiles, Leather & Clothing.	4.9	4.1	4.0	4.0			4.5	4.5	4.5				4.4	4.5	4.4	4.9	4.0
All Other Manufacturing Industries.	2.6	2.8	2.7	2.6			3.3	4.3	3.9				3.4	4.3	3.3	4.3	2.6

CHANGES IN UNEMPLOYMENT.

	Δ July.	Δ Aug.	Δ Sept.	Δ Oct.	Δ Nov.	Δ Dec. Sept.- Dec.	Δ Jan.	Δ Feb.	Δ March.	Δ April	Δ May.	Δ June. Feb.-June.
Food, Drink & Tobacco.	-0.1	+0.2	+0.2			+0.2	+0.6	+0.1				-0.7
Chemicals.	0	0	0			+0.1	+0.1	-0.1				0
Metals.	-0.6	+1.1	+0.2			+0.4	+1.1	+1.1				-2.4
Engineering & Electrical Goods	-0.2	+0.4	0			0	+0.4	-0.1	N.A.	N.A.	N.A.	-0.7
Ship Bldg. & Marine Engineering.	-0.1	-0.2	0	N.A.	N.A.	+0.9	0	-0.2				+0.4
Vehicles.	0	0	-0.1			+0.1	0	0				+0.5
Metal Goods, N.E.S.	0	0	+0.1			+0.1	+0.1	0				0
Textiles, Leather & Clothing.	-0.8	-0.1	0			+0.5	0	0				-0.1
All Other Manufacturing Industries.	-0.2	-0.1	-0.1			+0.9	+1.0	-0.4				-0.5

(c) Simultaneous improvement: British Manufacturing Industries:

The effects of the simultaneous correction for the level of activity and other factors is investigated in this section. It is advanced above that ignoring the level of activity in the specification of the aggregate production function is likely to bias the coefficients of labour and capital. Also it is likely to lead to a bias in the estimated residual variance. Moreover, the bias of the coefficient of the variable which is measured by its stocks is likely to be high. The intention of this section is to provide the relevant evidence in the form of a condensed comparison between alternative estimates of the aggregate production functions. The specification of the function involves:-

a. ignoring completely the degree of capacity utilization
b. correcting for unemployment of labour only
c. correcting for the degree of capacity utilization
d. correcting for the structure of capital
e. correcting for the vintage of capital, and
f. correcting for capital structure and vintage.

The estimates regarded below pertain to British manufacturing industries.

1. Ignoring completely the under-utilization of labour and capital, each being measured by available stocks, (i.e. insured labour and net stocks of all fixed assets), the estimated Cobb-Douglas production function is given by (8.1.9). Equation (8.1.9) will be treated as the traditional specification of the production function with which the other specifications are compared below.

2. Correcting only for unemployment of labour by using numbers in employment rather than insured employees: the estimated Cobb-Douglas production function is given by (8.1.10). It is clear from comparing equation (8.1.10) with (8.1.9) that correcting for the unemployment of labour has led to a 5 per cent explanation of the residual of the trad-

itional specification of the aggregate production functions. Moreover, a slight increase in the sharpness of the labour and capital coefficients is recorded.

3. Correcting for the degree of capacity utilization while measuring labour and capital by the available stocks gives the production function assessment (8.1.11). Comparing (8.1.11) with the traditional specification shows that correcting for the level of activity provides an explanation for 37.5% of the residual. Also a marked increase in the sharpness of the coefficients of labour and capital occurs.

4. Correcting for the unemployment of labour, (i.e. measuring labour by employees in employment, as well as the degree of capacity utilization: the Cobb-Douglas form of production function assessment is given by (8.1.2)

Comparing (8.1.2) with (8.1.11) provides evidence supporting the view that correcting for the degree of capacity utilization plays the part of transforming the factors of production which are measured by their stocks to a flow of services. In the assessment (8.1.11) both labour and capital are measured by their stocks while in (8.1.2) only capital is measured by its stock, the introduction of the degree of capacity utilization in the two functions leads to the startlingly complete agreement between labour elasticities and capital elasticities in the estimates of both equations. Since the degree of capacity utilization has to take care of the errors of specifying labour and capital by measuring each by its stocks in (8.1.11) the elasticity of the degree of capacity utilization is higher than its counterpart in equation (8.1.2) in which a correction is only needed for the error of specifying capital. This indicates that the degree of capacity utilization variable may stand as a catch-all for the influence of some of the factors which are not corrected for.

5. Correcting for the degree of capacity utilization, the unemployment of labour, then drawing a distinction between capital structures provides the

production function assessment (8.1.4). Comparing this with the traditional specification provides an explanation for 35 per cent of the residual. Comparing equation (7.1.4) which corrects for the structures of capital and unemployment of labour with (8.1.4) which allows in addition for the level of activity shows that the amount explained of the residual due to correcting for the degree of capacity utilization alone is almost 30%.

6. Correcting for the degree of capacity utilization, the unemployment of labour, and distinguishing between two vintages of capital: Equation (6.1.8) of chapter VI provided support for the mainly empirical view that old capital stands as a handicap for industrial growth and efficiency. It may be recalled that the coefficient of old capital was negative and significant at the 5% level while the elasticity of modern capital was positive, significant at the 0.1% level, and more than 41 per cent greater than the elasticity of the average age of capital as indicated by equation (6.1.4). The estimation of equation (8.1.12) which corrects in addition to the level of activity represents further support for the main conclusions derived from equation (6.1.8). It is beneficial for industry to rely less and less on older vintages of capital and to work hard in the direction of modernizing the capital equipment they use.

The simultaneous introduction of the degree of capacity utilization and the correction for the vintage of capital allowed 67.5% of the residual of the traditional specification (8.1.9) to be explained. The introduction of the degree of capacity utilization alone allowed a 35% explanation of the residual of equation (6.1.8).

It is to be noted that all the coefficients of equation (8.1.12) are highly significant except the coefficient of older vintages of capital. The latter is significant at the 10% level. However, if the older vintages of capital variable is removed, (equation (8.1.13)), all other variables coefficients remain highly significant while the explanatory power corrected for the degrees of freedom fell slightly from 0.987, equation (8.1.12), to 0.985, equation (8.1.13).

7. Correcting for the degree of capacity utilization, the structure of capital and for the vintage of plant and machinery:

In the estimation of the Cobb-Douglas form of production function (8.1.14), labour is measured by the numbers employed, capital is measured by modern plant and machinery and a correction is introduced for the degree of capacity utilization. Equation (8.1.14) provides a further support for equation (7.1.12) where the correction for the degree of capacity utilization by the former indicates that the elasticity of modern plant and machinery is still the dominant and most significant as compared with the negative and statistically insignificant coefficient of the older vintages of plant and machinery.

If the older vintages of plant and machinery variable is removed equation (8.1.15) the explanatory power corrected for the degree of freedom improves slightly and the coefficients of the remaining variables stay highly significant. The introduction of a correction for the degree of capacity utilization equation (8.1.15) allows more than 32% of the residual of equation (7.1.14) to be explained. If it is recalled that modern plant and machinery represents those with vintage seven years and less, this finding may thus be regarded as further support for the view that it pays to rely less and less on old plant and machinery and to insist more and more on acquiring the most up to date equipment. This view is supported even more when a correction for the degree of capacity utilization is introduced.

CHAPTER IX

THE MEASUREMENT OF LABOUR

THE MEASUREMENT OF LABOUR

A: Theory:

With the exception of equation (5.24) above all other equations assume homogeneity of the labour factor and this is unrealistic. Age-sex composition, skill, education, etc., in short structural and qualitative aspects of labour vary from one firm to another and from one industry to another. Today's worker is undoubtedly more skilful, better educated and more highly trained than his temporal predecessor.

By learning new skills, a worker is able to move to a better job either in the same industry or in another industry where he will receive greater pay as a remuneration for his increased marginal contribution to output. If some industries tend to employ higher quality labour (or mainly males), then it may be that in these industries wages are the highest. To the extent that labour moves into higher paying industries, such movement will show up as inter-industry technical progress. In other words part of the technological progress will be due to the re-allocation of resources from the relatively backward to the progressive industries. In this case the technological progress achieved is mainly the outcome of learning by doing as distinct from:-

(a) investment in new capital equipment that incorporates the latest technical improvement, and

(b) investment in technology

In Chapter V it is shown that ignoring the heterogeniety of labour involves a wrong specification which is likely to introduce bias in the estimated technical efficiency as well as in the estimated coefficients of other input factors. Also it is pointed out that there are dangers in relying on wrongly specified production functions in projecting the amount of resources necessary to achieve certain levels of activity at a future date. One way of expressing qualitative aspects formally is -

$$O = f(L_s, L_n, K, A) \qquad (9.1)$$

where L_s and L_n refers to skilled labour and non-skilled labour respectively.

Although equation (9.1) does not explicitly express the need for a distinction between qualitative and structural aspects of capital it is understood that such improvements must not be disregarded merely because of the attempt to improve the measurement of labour. In order to avoid repeating what has already been said as well as complicating the equation forms and the discussion, K will be used to express capital in the way in which it has already stipulated rather than in its literal sense.

In the absence of data on the number of skilled labour, which is the case for British as well as Scottish manufacturing industries in 1962, average hourly rates, and average weekly earnings are usually recommended as proxies for labour quality. The formers, which are not available on an industry basis but on an occupational basis, may be overshadowed by lags and leads in wages disputes and settlements and back-dated payments involved.

If average weekly earnings are used as a proxy for labour quality, then higher than average weekly earnings may simply reflect a greater number of weekly hours worked, i.e. increased intensity of labour utilization, rather than higher skills. They may thus reflect a mixture of the strength of labour bargaining power, labour quality and the degree of capacity utilization.

On the other hand, average hourly rates are distorted as a proxy of quality by the fact that differences in wage rates might neglect compensation for inferior jobs, worse working conditions, etc., rather than increased skill.

The sex structure dimension is rich in data availability for British and Scottish manufacturing industries. It provides a chance for improving the specification of labour and thus allowing the estimated production function to be much more useful in assessing inter-industry efficiency.(1) Also it proves promising in laying down policy recommendations. Since it is known that women are, in practice, employed in jobs requiring less skill, then in addition to reflecting sex structure, a distinction between males and females reflects in part labour quality. However, there is a point of weakness in sex data in particular as well as in employment figures in general. The official statistics do not distinguish between part-time and full-time, the statement being made that "Part-time workers are counted as equivalent to whole-time workers". Thus the distinction between males and females becomes, in one hand, necessary since it is known that women are concentrated more in part-time jobs, while on the other hand the distinction between males and females, without allowing for the above mentioned fact, biases the reflected relative efficiencies of males versus females; it would exaggerate somewhat the true difference.

B: Application:

The form used to distinguish between males and females is:-

$$O = f(L_m, L_w, K, A) \qquad (9.2)$$

where L_m and L_w refer to male and female employees respectively.

In order to correct for labour and capital structure, the following form is used:-

$$O = f(L_m, L_w, K_p, K_o, A) \qquad (9.3)$$

where all variables are defined above.

---

(1) Reference should be made here to the improvement made in recent years by combining age/sex structure via assigning weights according to the relative wage rates of others to adult male wage rates. It is preferable on the grounds of saving degrees of freedom when they are so much needed. Nevertheless, this approach is inferior to a direct distinction approach because of the arbitrariness of the weights used.

The estimates of (9.2) and (9.3) and other equations which take account of the vintage of capital, and /or the degree of capacity utilization for British manufacturing industries are given by the top section of Table (9.1). The equations which take account of the structure of labour and/or the structures of capital for Scottish manufacturing industries are given by the other section of Table (9.1).

In investigating the effect of correcting for the structures of labour the main emphasis is laid on the need to avoid the specification error which results from treating all labour as homogeneous when there is a large and significant difference between males and females elasticity. Such an error is likely to impart a bias in the estimated technical efficiency (as well as in the estimated coefficients of the production function).

Moreover, the consistency of the estimates arrived at will be indicated by regarding the simultaneous effect of correcting for the structure of labour and avoiding other sources of specification errors (see Chapters V, VI, VII and VIII) as follows.

Firstly correcting for the structure of labour only in -

(a) the production function which explains net output:

1. Equation (9.1.2) for British manufacturing industries indicates that the males elasticity is 2.4 times as large as the females elasticity.
2. Comparing equation (9.1.2) with (6.1.4) indicates that the amount explained of the residual as a result of correcting for the structure of labour alone exceeds 18%.
3. Equation (9.1.17) for Scottish manufacturing industries shows that the males elasticity is 2.8 times as large as

Table (9.1) Sex structures in the specification of the Aggregate Production Function

No.	Dept.	Constant	Males Abst.	Males Log	Females Abst.	Females Log	All Assts. Abst.	All Assts. Log	Coefficient of Plant & Machinery Abst.	Plant & Machinery Log	Other Structures Log	Modern All Log	Modern Assets Plant & Machinery Log	Degree of capacity utilization Log	Intermediates Abst.	Intermediates Log	R^2	$\bar{R}^2$
									British Manufacturing Industries									
1	NO	-41·61	0·895 (0·095)		0·835 (0·139)		0·381 (0·055)										0·965	0·960
2	lnNO	2·642		0·542 (0·060)		0·223 (0·035)		0·290 (0·048)									0·973	0·969
3	lnNO	2·857		0·538 (0·070)		0·223 (0·036)				0·176 (0·080)	0·115 (0·118)						0·973	0·967
4	NO	-40·80	0·966 (0·105)		0·926 (0·160)				0·472 (0·085)								0·954	0·947
5	lnNO	2·824		0·576 (0·058)		0·229 (0·036)				0·243 (0·042)							0·971	0·967
6	GO	-26·5	0·870 (0·083)		0·646 (0·140)		0·293 (0·058)								0·1073 (0·0027)		0·9975	0·9969
7	lnGO	1·846		0·165 (0·037)		0·073 (0·023)		0·131 (0·045)								0·621 (0·049)	0·9891	0·9866
8	GO	-22·8	0·902 (0·085)		0·658 (0·148)				0·349 (0·076)						0·1093 (0·0027)		0·9972	0·9966
9	lnGO	1·868		0·179 (0·035)		0·074 (0·023)				0·102 (0·039)						0·635	0·9889	0·9865
10	lnNO	2·770		0·554 (0·056)		0·208 (0·034)		0·293 (0·045)						5·213 (2·718)			0·978	0·973
11	lnNO	2·946		0·580 (0·055)		0·215 (0·035)				0·244 (0·040)				4·834 (2·854)			0·975	0·970
12	LnNO	2·979		0·495 (0·511)		0·234 (0·028)						0·296 (0·037)					0·982	0·979
13	LnNO	3·071		0·550 (0·055)		0·236 (0·033)							0·241 (0·037)				0·976	0·972
14	lnNO	3·077		0·501 (0·045)		0·223 (0·028)						0·294 (0·036)		3·846 (2·273)			0·984	0·981
15	lnNO	3·174		0·555 (0·053)		0·224 (0·033)							0·240 (0·036)	4·075 (2·648)			0·979	0·974
									Scottish Manufacturing Industries									
16	NO	-4·042	0·788 (0·102)		0·664 (0·171)		0·413 (0·092)										0·946	0·937
17	lnNO	2·753		0·596 (0·086)		0·213 (0·044)		0·225 (0·079)									0·953	0·945
18	NO	-4·001	0·846 (0·104)		0·802 (0·176)				0·499 (0·131)								0·937	0·927
19	lnNO	2·873		0·623 (0·080)		0·219 (0·044)				0·189 (0·067)							0·952	0·945
20	GO	-1·268	0·779 (0·073)		0·356 (0·144)		0·166 (0·088)								0·113 (0·003)		0·9977	0·9972
21	lnGO	1·625		0·168 (0·036)		0·057 (0·019)		0·0972 (0·0486)								0·668 (0·050)	0·9913	0·9893
22	GO	-1·201	0·791 (0·070)		0·373 (0·145)				0·204 (0·105)						0·204 (0·003)		0·9977	0·9972
23	lnGO	1·664		0·178 (0·035)		0·059 (0·019)				0·081 (0·040)						0·671 (0·049)	0·9913	0·9893

the females elasticity. Moreover, comparing equation (9.1.17) with (6.1.12) indicates that the amount explained of the residual exceeds 8%.

(b) the production function which explains gross output:

1. Equation (9.1.7) indicates that the males elasticity in British manufacturing industries is 2.3 times as large as the females elasticity. Comparing equation (9.1.7) with (6.1.6) shows that the amount explained of the residual exceeds 7%.

2. Equation (9.1.21) for Scottish manufacturing industries shows that the males elasticity is 2.9 times as large as the females elasticity. Moreover, comparing equation (9.1.21) with (6.1.15) indicates that a 2% of the residual is explained.

Secondly correcting for the structure of labour and for the structure of capital -

(a) in the production function which explains net output it is indicated that:

1. the males elasticity for British manufacturing industries is 2.5 times as large as the females elasticity, see equation (9.1.4). Comparing equation (9.1.4) with (7.1.4) the amount explained of the residual as a result of correcting for the structure of labour is 10.8%.

2. in Scottish manufacturing industries, equation (9.1.19), the males elasticity is 2.9 times as large as the females elasticity. 5.2% of the residual is explained; Compare equation (9.1.19) with (7.1.16).

(b) In the production function explaining gross output of British and Scottish manufacturing industries (equations (9.1.9) and

(9.1.23)) the males elasticity is 2.4 and 3.0 times as large as the females elasticity respectively. The amount explained of the residual is 2% (compare equation (9.1.9) with (7.1.9) for the British sector).

Thirdly, correcting for the structure of labour, for the structure of capital, and for the vintage of capital:-

Equation (9.1.13) for British manufacturing industries indicates that the males elasticity is 2.3 times as large as the females elasticity. Comparing equation (7.1.14) in which a correction is made for the structure and vintage of capital (and from which other types and vintages of capital variable is removed on the grounds of low significance) with equation (9.1.13) which corrects in addition for the structure of labour, indicates that almost 10% of the residual is explained by correcting for the structure of labour.

Fourthly, a correction for the structure of labour and for the degree of capacity utilization is made. (It is important to note that the number of employees given by the official statistics and hence used in the estimates of this study ignores the distinction between full-time and part-time. Since females are concentrated in part-time employment more than males, then taking account of sex structure is likely to correct partly for the degree of capacity utilization (unless a correction is introduced for the average number of hours worked). The implications of this remark are:-

1. The simultaneous effect of correcting for the structure of labour and the introduction of the degree of capacity utilization provided an explanation of the residual lower than the sum of the explanation provided by introducing the two corrections separately.

   The findings as provided by equations (9.1.10), (9.1.11), (9.1.14) and (9.1.15) indicate that the simultaneous correction for the structure of labour and for the degree of capacity utilization led to a considerable loss in the sharpness of the degree of capacity utilization coefficient. Its significance can be attained on the 0.20 instead of 0.01 level.

However, the considerable difference between males and females elasticities is not affected by the lower significance of the degree of capacity utilization's coefficient. The ratio of the former to the latter is more than 2.

2. Leaving out of consideration theaverage hours worked by males and females, the number of employees is likely to over-estimate the flow of females services relative to the flow of male services and, consequently, under-estimate the relative contribution of females vis-a-vis males towards the production processes. An evaluation of the likely bias is not attempted by this study.

The implication of these findings, from an econometric point of view is revealing; it indicates the necessity for taking account of the structural aspects of labour, if a more accurate specification of the labour factor in the production function is to be achieved, as well as if the bias otherwise involved is to be avoided. The main source of bias is the considerable difference between the output elasticities with respect to males and females and the considerable stability in the estimated difference.(1)

The policy implication of this finding is treated in Chapter V. There is, however, one more aspect of the implication of this finding in practice. The aggregate production function is a tempting tool for the comparison of inter-industry efficiency as well as inter-temporal technological progress.

---

(1) The difference between males and females elasticities is statistically significant at the 1% level.

By ignoring the structure of labour, the relative Technical Efficiency (or the rate of technological progress) of those industries which employ more females will be biased downwards and of those who employ mainly males will be biased upwards (even if part-time employees are counted with greater accuracy).

CAPTER X

SCIENTIFIC AND TECHNOLOGICAL EFFORT

SCIENTIFIC AND TECHNOLOGICAL EFFORT

A: Theory:

Technological progress in the narrow sense is mainly the outcome of scientific and technological effort. In any industry this effort originates from both that industry and industries supplying plant and equipment, raw materials, fuel, components and other services. It can also be required from specialized research and development establishments and from abroad through imports.

The main products of scientists and technologists' effort is the "production of knowledge" which is defined as any activity by which someone learns of something new to him. Thus disclosure, dissemination, communication, diffusion and creation of knowledge becomes part of a wider concept of "production of knowledge".

As an economy develops and as a society becomes more complex, efficient organisation of production, research and development, on-the-shop floor productive activities, foreign trade, and government, etc., require increasing division of labour between "knowledge production" and physical production. A quite remarkable increase in the division of labour between pure "intellectual activity" and largely physical performance has occurred in all sectors of economic and social organisations.

The intellectual activities would thus extend beyond the familiar research and development activities to those more concerned with co-ordinating the production and application of technical knowledge to production, administration, the assessment and marketing of physical output (or services), in short, scientific management. Scientific and technological activities should also incorporate the efforts of those who are concerned with the implementation of research and development output on-the-shop floor. These three basic scientific functions have been selected to represent most of the scientific effort in industrial firms.

The line taken by this study is mainly to assess the contribution of scientific and technological effort within the framework of productive activities, giving due regard to basic scientific functions. Also an allowance for variations in the structure and quality of the labour force and capital equipment, as well as the level of activity, ought to be regarded.

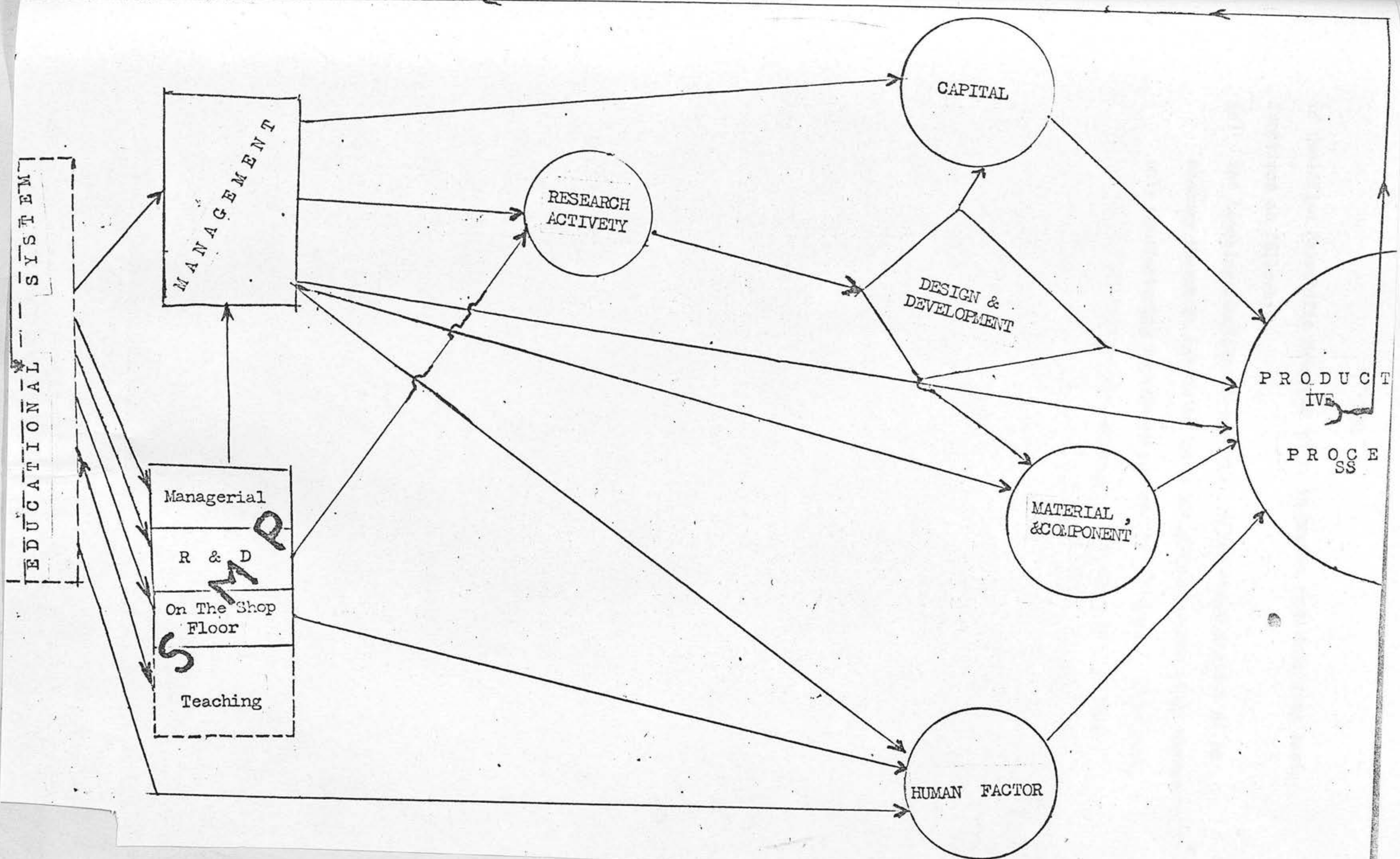
It should be noted that the process of technological innovation within a given production system is a self-generating one. An economy would prosper faster and be able to sustain a steady rate of growth if it enjoyed a growing number of scientific brains complementing, (or compensating for any deficiency in), other natural resources. The contribution of scientific brains used to be treated as an indistinguishable part of technological progress. The presumption is the existence of an initial scientific base.(1)

In order to widen further the scientific base so as to meet the growing need for intellectual activities,the growth of an economy should allow the needed expansion in educational facilities. Whether the causal relationship runs from the growth of Gross National Product to the educational system to increasing the scientific base or from the scientific base to the growth of Gross National Product is immaterial, since it is a self-generating cycle. The self-generating process of technological innovation is illustrated by chart (10.1) with special emphasis on the role

---

(1) An economy may live temporarily on hired scientific effort but to sustain and increase the rate of its development it should have its own and increasing scientific base.

A SELF GENERATING PROCESS



of Qualified Scientific Manpower which is broken down into four basic functions as follows:-

(a) the teaching function is essential in the wider context of an economy though it has to be taken as given when the study covers only manufacturing industries or individual firms. This part has been indicated in the chart by surrounding the teaching function and the educational system by broken line emphasising its exogeneous nature vis-à-vis the underlying model.

(b) The managerial function plays a dominant part in the educational system, the productive system, and the process of technological innovation, etc. A distinction has been drawn between scientific and non-scientific management. The intention is to stress the importance of scientific management in speeding the rate of technological progress.

With a wider base of scientifically minded management supporting non-scientific executives, the process of technological innovation is expected to be more efficient. As far as technological creation and application is concerned, scientific management is regarded as responsible for choosing amongst a wide range of projects, and in assessing for each the potential growth and commercial possibilities. On the diffusion front scientific management is in a position to appreciate the technological progress embodied in marketable capital equipment, raw materials and fuel, etc. They thus aid the diffusion process by introducing new and improved equipment, processes, components, etc. Even if the latest technological improvements are not marketable due to technical lead and industrial secrecy considerations, a scientific management is invaluable in spreading technological knowledge through links with other leaders in the field.

The managerial activities affect directly the productive process by selecting the product mix, which also extends to the share of new and improved products in the total production. It is also vital for deciding upon the degrees of utilization and the appropriate combination of input factors where the state of art and technology allows such flexibility. The dominant role of the managerial function in all aspects of firms' activities is indicated by chart (1). This chart also allows for the increasing part played by scientists and technologists in modern management. Social scientists as effective managers are not an exception; however, they are unfortunately excluded by definition from the triennial surveys of Qualified Scientific Manpower.(1)

(c) The necessity of a wide base of "intellectual contribution" on-the-shop floor cannot be dispensed with by qualified scientists and technologists occupying managerial posts and research and development activities. Although they cannot be regarded as creators of technological innovation, their part in the application and diffusion of technical innovations is obvious. They represent the basic link between the research and development department and the production department, and are the specialists who both appreciate the products of the research and development and ensure its appropriate application on a commercial scale. Moreover, they appreciate and recommend the instalment of capital equipment, raw materials, components, etc. which incorporate the latest know-how.

(d) The role of research and development effort whether it is represented by the main contributors "brain workers" or by all research and development expenditures in the process of creating technological innovation is well known. The majority of the previous work in the "production of knowledge" has concentrated on this particular

---

(1) It is to be noted that the U.K. is one amongst the very few countries which exclude social scientists from scientific manpower surveys. Most other countries do include them, though may favour recording them separately.

area of scientific effort. The research and development effort does not stop in practice with the discovery and first commercial production of, say, a raw material. For instance, in the plastic industry case the first commercial production was only the start. It was followed by years of applied research and development work to explore the potential applications, to modify the material and create a variety of grades suited to each application, to blend it with other materials, to improve and cheapen the production process.[(1)]

A productive unit having a large number of Qualified Scientific Manpower doing applied research and development in a given field will find it easier to explore other related fields. Advances in any one field studied by a research and development team will help progress in closely related fields. Even when the technological lead of invention and innovation is gained by another competitor at home or abroad, firms with a large team of scientific and technological researchers are frequently the first to imitate the process. This is possible because research and development in all technologically advanced firms is proceeding to some extent on similar lines so that when a major new discovery is made in one of them, the teams in other leading firms are able more quickly to assimilate and imitate it. Moreover, frequently, the obstacles to imitation may be with patents rather than in the lack of know-how. Furthermore, the giant firms possessing larger research and development department are in a position to reach an agreement with one another for the exchange of know-how and any firm with its own research and development projects to offer may be able to obtain favourable terms.

---

(1) C. Freeman. "The Plastic Industry: A Comparative Study of Research and Innovation". N.I.E. Review. Vols. 26, 1963. pp. 22-62.

Whether to use research and development expenditures or scientific personnel to approximate the input of scientific effort in research and development is mainly a matter of coping with an existing data situation more than being based on technical considerations. On the one hand the real technology innovation effort when measured through expenditures may be obscured by the fact that the purchasing power of money deteriorates over time. Measuring the speed of technological innovation of a given industry by the employment of scientific and technological personnel, other things being equal, will give a clearer picture of its technological progress. On the other hand, the use of the number of qualified scientific manpower employed on research and development is not free from criticisms. In an inter-temporal and inter-industry situation, the changes and variations in the employment of Qualified Scientific Manpower could be volatile and almost accidental if there was a strong case of purchasing technological knowledge embodied in the factors of production used, in the method of production, and a greater possibility of substitution between Qualified Scientific Manpower and other professions. For instance, if some chemical firms hired many chemists and others relied extensively upon either other industries (such as research and development firms) or other types of workers where substitution is possible, then any underlying continuity of an industry's effort in technological innovation effort would not ensure continuity of Qualified Scientific Manpower employment.

A distinction has been made on the chart between development and design on the one hand and research on the other. This distinction is drawn not in order to claim any clear-cut division between the two activities, but rather to stress the widely accepted notion that in an industrial firm there is generally no place for academic, basic or pure research. The latter is mainly the pre-occupation of universities, non-profit organizations, and mainly or heavily government-financed projects. All these are regarded here as falling within the scope of educational system and other sectors of the economy and therefore, may be taken as exogeneous to the production system.

The process of technological innovation may benefit the final product directly through the introduction of new and improved production methods and changing the pattern and mix of products so as to meet changing tastes, provide greater satisfaction, and fulfil increasing needs. Technological innovation may effect the production process through changing the type, the form, the quality and the degree of utilization of resources. For instance the introduction of new and improved methods, processes, equipment, raw materials, human skills, etc., which embody the latest know-how are some aspects of the attempts to increase the efficiency of resource utilization and may aim at cost minimization. In other words, greater new and improved output is being produced with greater efficiency and less resources. These direct and indirect effects of technological innovation on the production process is being indicated by the chart as research and design affecting directly the productive process through new and improved processes and methods, capital, raw material, fuel and components etc.

It is highly likely that the trend is in favour of substituting Qualified Scientific Manpower for other types of personnel in deserving activities, rather than substituting lower qualifications for jobs used to be filled by Qualified Scientific Manpower. Also, a rational recruiting policy is likely to be adopted by management. In the sense that they do not employ Qualified Scientific Manpower in jobs below their full ability. A highly Qualified scientist wastes his precious time in "tube-washing" or an engineer doing the work of a draftsman are examples of misallocation of scarce resources. In a situation of manpower shortage market prices would not reflect the value of Qualified Scientific Manpower. It follows that a firm will employ, say, an engineer up to the point where the output attributable to him is at least equal to the salary being paid to him. Yet, from a social point of view, he could still be used more efficiently elsewhere. However, the situation of mis-use of Qualified Scientific Manpower should not be extended to the special dynamic problem of hoarding Qualified Scientific Manpower by some firms either in the expectation of future contracts or in order to demonstrate their capacity to perform additional work prior to a successful bid for a contract.(1) The question of the more effective utilization of highly qualified personnel is receiving some attention but apparently not as much as it deserves. Some of the efforts of Scientific manpower could be saved through greater operational flexibility, by increasing the ratio of technicians to engineers and research scientists in order to reduce the amount of "test tube washing" and "paper shuffling" engaged in by highly qualified personnel. Of course variations in such a ratio from one industry to another are partly the result of different research demands, the degree of mechanization, and the types of goods produced, etc. Further within an individual industry there is also wide range in the ratio. Here it is to be noted that handing over to technicians and supporting staff more and more of the work previously done by highly qualified personnel in an attempt to achieve better allocations of resources, involves modification of some productive and research and development techniques.

Thus Scientific effort is likely to be the main contributor to the process of application and diffusion of technological innovation. That process itself is an important part of technological progress. Measuring scientific effort by the input of Qualified Scientific Manpower involved in three basic scientific functions covers the aspects of managerial effectivness, inventive-innovative output achieved by the research and development

---

(1) A. A. Alchian, K.J. Arrow and W.M. Capron "An Economic Analysis for Scientists and Engineers". The Rand Corpn. 1958.

function, and the efficient commercial application on-the-shop floor by Qualified Scientific Manpower.

Scientific effort broken down to these three functions should greatly help the explanation of the productive process, growth and variations. It is supposed to reflect both the direct and indirect effects of technological innovation process on the output produced. The direct effect involves increased, new and improved products. The indirect effect involves saving in resources utilization or cost minimization.

B: Assumptions:

Further assumptions associated with the present study of scientific effort are as follows:-

1. The only motive behind the employment of Qualified Scientific Manpower in an industrial firm is a genuine place for their efforts in the firm's activities.
2. Qualified Scientific Manpower are homogeneous.
3. The number of Qualified Scientific Manpower performing a given scientific function represents the scientific input of that function towards the production process, i.e. the stock of Qualified Scientific Manpower surveyed at a given time is assumed to represent the flow of their service during the concerned period.

The implications of assumption (1) are:-

(a) There is no "conspicuous consumption" of Qualified Scientific Manpower in the sense that they are not employed for prestige or "window dressing" reasons. However, the conspicuous consumption could be a testable hypothesis but made assumption because it is in practice extremely difficult to test . It should be necessary to discover cases in which some firms persistently made less progress, lower efficiency, and poor profits, etc. than others in similar conditions except for an appreciable increase in the percentage of Qualified Scientific Manpower employment.

(b) The "band-wagon effect" is not the main reason for increasing the density of Qualified Scientific Manpower, (i.e. the ratio of Qualified Scientific Manpower to total employees). It may be that the large number of Qualified Scientific Manpower already in employment are likely to recruit more Qualified Scientific Manpower in turn.(1)

Assumption (2) implies that Qualified Scientific Manpower who perform a given scientific function are homogeneous. Clearly this assumption is an abstraction from reality though it is resorted to for practical consideration imposed by data availability. It is obvious that scientific talent, imagination, drive, and experience etc. do vary from one individual to another depending upon personal character, the qualifications obtained, the duration of study, the training in various courses, and the years spent in performing certain types of work, etc. Moreover, the same talented person would do much better if equipped with greater facilities, relieved from "Test-tube washing" and "paper shuffling", surrounded by an encouraging atmosphere and directed towards carefully planned projects, etc. If data were sufficient it would have been preferable to allow for such factors so as to satisfy the requirements of a standardized Qualified Scientific Manpower concept.

---

(1) This situation is similar to what is traditionally known as the 'Parkinson's Law' which implies that administration tends to create more work for more administratives.

Assumption (3) implies that each qualified individual works on the average a number of hours similar to that of the rest of qualified personnel. The rationale of this treatment is based on the prevailing convention in practice that Qualified Scientific Manpower are seldom rewarded for the extra hours they spend in order to meet the obligation of their duties. Otherwise, the number of "standard scientific hours" would be the only sensible measure of the flow of Qualified Scientific Manpower services.

C: Regional Comparison of Scientific Contribution to Production: Theory:

Generally speaking, inter-regional disparities in any area of economic endeavour may lead to broad economic difficulties and create additional economic disparities among various regions and more difficult tasks for the planners. If things are left completely free from government intervention, regional disparities may affect among other things:-

(a) the population flow between regions

(b) the size, quality, and interest of educational institutions

(c) the ability to recruit (or preserve already employed) highly trained labour and highly qualified personnel

(d) the location, entry, growth and specialization of new and established firms

(e) the balance between broad economic sectors and the structure of each sector.

As far as Qualified Scientific Manpower is concerned, the question is not what difference is there between an existing inter-regional distribution of scientific talent and the optimum allocation, since the answer to that question may not exist. A more practical attitude is to evaluate the extent to which there are in fact inter-regional disparities in scientific talent and pin-point the privileged and underprivileged areas. It may be be necessary to watch the trend of scientific talent within the underprivileged areas and perhaps to compare rates of change of the number of Qualified Scientific Manpower of the less privileged was with, say, the national average. If a tendency towards deterioration remained or intensified, steps should be taken to correct such deterioration in order to avoid widespread problems.

An alternative method is to compare the relative contribution of Qualified Scientific Manpower towards the productive process between two regions at a given point in time using the production function. In fact this is the line taken by the present study, though scientific talent evaluation and comparison is limited to the research and development effort because of data available. The year is 1962 and British Manufacturing Industries and Scottish Manufacturing industries are the two cross-sections studied.

The line taken here is that the employment of Qualified Scientific Manpower in research and development is the main factor of scientific effort devoted mainly to attaining a technological lead or catching up with technical leaders. The inventive-innovative effort of the research and development personnel is, moreover, regarded as the main component of investment directed at improving technology in the future. In other words, the production of to-day should be regarded as a function not only of currently employed resources but also of the resources devoted in previous periods for improving technology. Furthermore, as has been proved to be the case, the current productive process benefits not only from lagged inventive-innovative effort, but also from current effort.

D: Application:

There is increasing awareness that a production function that expresses output as a function of the conventional factors of production tends to be less accurately specified by leaving out scientific effort devoted to current production as well as scientific effort devoted to improving technology. The result is to bias upward the estimated variance of technical efficiency. An explicit introduction of scientific effort in the production function, on the other hand should tend to improve its specification, should reduce the bias involved, and provide a better understanding of strategic factors in technological improvement.

(a) The suitability of alternative forms for application:

The form of production function to be used in evaluating the scientific effort must be rather modest compared with form (5.24) above in the sense that it must contain far less explanatory variables. This is necessitated by the lack of sufficient data on scientific personnel, e.g. Research and Development employees are the only obtainable figures for Scottish manufacturing industries. Also the availability of only 23 observations makes it difficult to meet the requirements of a fairly comprehensive production function. A suitable form of production function may be:-

$$O = f(L, K, R, F, M, A) \qquad (10.1)$$

where R measures Research and Development effort either as expenditures or Qualified Scientific Manpower employed on research and development activities. F refers to the employment of Qualified Scientific Manpower on-the-shop-floor. M represents the employment of scientific and technological management.

In applying equation (10.1) to British manufacturing industries, the presence of multi-collinearity was the reason for abandoning it in favour of a more simple form, which either combines all three functions of scientific effort in one figure, i.e. total scientists and technologists (Ts) in the form:-

$$O = f(L, K, T_s, A) \tag{10.2}$$

which, since it requires knowledge of total qualified personnel, is only applicable to the United Kingdom; or the form that can be applied to both British Manufacturing industries and Scottish manufacturing industries, which is:-

$$O = f(L, K, R, A) \tag{10.3}$$

An equally applicable form for British manufacturing industries is:-

$$O = f(L, K, F, A) \tag{10.4}$$

Also the possibility of a lagged effect on the productive process will be investigated by an equation of the form:-

$$O_t = f(L_t, K_t, R_{t-s}, A) \tag{10.5}$$

where R_{t-s} is the research and development effort that was undertaken s years ago. The length of s in a simple lag form may be estimated rather than assumed. However, R_{t-s} may as well be replaced by a distributed lag of research and development activity though the limited data available prevents application here.

Therefore, the model has been adapted according to equations (10.2) - (10.5) so as to allow for estimating the contribution that results from scientific effort in a form that affects measured industrial product. That is, the production efficiency or technical efficiency measure based upon the national product concept will be biased upwards to the extent that output increases brought about by new products, improved processes, and production techniques etc., are not attributed to their main creators.

(b) <u>The explicit introduction of research and development in the British function</u>:

Table (10.1) presents the results of introducing the research and development separately and in combination with other improvements in the

Table (10.1) The input of Scientific and Technological Effort in the production function of British Manufacturing Industries

Dependent	Constant Term	Total number in employment Abst.	Total number in employment Log	Modern Capital Abst.	Modern Capital Log	Modern Plant & Machinery Abst.	Modern Plant & Machinery Log	Coefficient of Degree of capacity utilisation Abst.	Coefficient of Degree of capacity utilisation Log.	All Fixed Assets Abst.	All Fixed Assets Log	Plant & Machinery Abst.	Plant & Machinery Log	Materials, Fuel, etc. Abst.	Materials, Fuel, etc. Log	R & D Abst.	R & D Log	R^2	$\bar{R}^2$	Eqn. No.
lnNO	2·081		0·741 (0·054)								0·272 (0·055)						0·0440[a] (0·0246)	0·971	0·966	1
lnNO	2·237		0·777 (0·051)										0·237 (0·050)				0·0370[b] (0·0262)	0·969	0·964	2
lnNO	2·286		0·725 (0·045)						7·598 (2·556)		0·294 (0·047)						0·0279[b] (0·0214)	0·980	0·976	3
lnNO	2·452		0·764 (0·044)						7·529 (2·319)				0·256 (0·044)				0·0204[c] (0·0232)	0·979	0·974	4
lnGO	1·464		0·228 (0·029)								0·0538[c] (0·0493)				0·675 (0·045)		0·0406 (0·0140)	0·9916	0·9897	5
lnGO	1·457		0·234 (0·028)										0·0375[c] (0·0425)		0·684 (0·044)		0·0412 (0·0149)	0·9914	0·9895	6
lnGO	1·692		0·219 (0·026)		0·0978 (0·0420)										0·641 (0·040)		0·0281 (0·0137)	0·9931	0·9915	7
lnGO	1·574		0·231 (0·027)				0·0555[b] (0·0385)								0·669 (0·041)		0·0347 (0·0151)	0·9919	0·9901	8
lnGO	1·629		0·223 (0·026)						3·256 (1·485)		0·0823[a] (0·0466)				0·654 (0·042)		0·0311 (0·0134)	0·9934	0·9915	9
lnGO	1·621		0·232 (0·026)						3·118 (1·516)				0·0597[b] (0·0406)		0·666 (0·041)		0·0317 (0·0145)	0·9931	0·9911	10
lnGO	1·857		0·215 (0·023)		0·116 (0·037)				3·277 (1·260)						0·627 (0·035)		0·0194[b] (0·0124)	0·9951	0·9936	11
lnGO	1·741		0·229 (0·025)				0·0725[a] (0·0357)		3·149 (1·425)						0·656 (0·038)		0·0256[a] (0·0143)	0·9937	0·9919	12
GO	-41·022	0·792 (0·060)								0·274 (0·051)				0·107 (0·002)		0·0183 (0·0071)		0·9980	0·9976	13
GO	-37·634	0·818 (0·064)										0·324 (0·070)		0·109 (0·002)		0·0181 (0·0077)		0·9977	0·9971	14
GO	-30·010	0·791 (0·058)		0·409 (0·073)										0·107 (0·002)		0·0181 (0·0069)		0·9981	0·9977	15
GO	-33·027	0·813 (0·063)				0·454 (0·096)								0·110 (0·002)		0·0202 (0·0075)		0·9977	0·9972	16
GO	-23·987	0·772 (0·053)						2409·3 (980·9)		0·298 (0·047)				0·106 (0·002)		0·0122[a] (0·0067)		0·9985	0·9981	17
GO	-2460·5	0·800 (0·058)						2476·1 (1084·2)				0·358 (0·064)		0·109 (0·002)		0·0117[b] (0·0075)		0·9982	0·9977	18
GO	-2292·0	0·773 (0·052)		0·440 (0·066)				2312·6 (953·2)						0·107 (0·002)		0·0125[a] (0·0065)		0·9986	0·9982	19
GO	-2382·4	0·795 (0·058)				0·497 (0·089)		2401·5 (1073·7)						0·110 (0·002)		0·0142[a] (0·0073)		0·9982	0·9977	20

a Significant at the 10% level

b " " " 20% "

c " " " 30% level and over.

specification of the production function of British manufacturing industries. The single improvement of regarding the input of research and development will be regarded here.

The estimation of the Cobb-Douglas form of (10.3) above, which explains net output is given by (10.1.1). (10.1.1) indicates that the research and development coefficients is significant at the 10% level.

The lack of sharpness of the research and development coefficient is attributable to the multicollinearity brought about by the high correlation between the research and development personnel and capital variables reaching 0.60. In spite of the indicated multicollinearity, the introduction of the input of science in the specification of the Cobb-Douglas net output function allowed 11% to be explained of the residual of the traditionally specified production function (6.1.4).

Moreover, the less powerful the effect of multi-collinearity on the research and development coefficient, the greater is the percentage explained of the residual due to the introduction of scientific input into the production function.

In the Cobb-Douglas net output function (11.4.7), the research and development is measured by expenditure rather than scientific manpower. The correlation of the former with capital being 0.51 is lower than the correlation between capital and research and development personnel. The sharpness of the research and development coefficient is increased to become significant at the traditional 5% level. Moreover the percentage explained of the residual rose to 16%.

In the linear production function explaining gross output (10.1.13) all the coefficients are significant at least at the 2% level. The percentage explained of the residual of (6.1.5) due to the introduction of scientific manpower in research and development reached 25%.

The multi-collinearity of the unrestricted Cobb-Douglas form explaining gross output (10.1.5) produced a large decrease in the sharpness of the capital coefficient which can only be significant at the 30% level but indicated the coefficient of research and development to be significant at the 1% level. In spite of the existence of multicollinearity in the estimated production function (10.1.5) the percentage explained of the residual of the traditionally specified production function (6.1.6) due to the introduction of research and development reached 28.5%.

In spite of the fact that multicollinearity is producing similar effects in both the net output and gross output functions, it seems that the harmful effect of multicollinearity is reduced by offsetting factors in the case of the gross output function.(1) In order to indicate the consistency of the findings of British manufacturing industries with the findings of the Scottish manufacturing industries as well as the consistency of the findings with respect to the explicit introduction of the input of research and development function, the gross output function in its linear and unrestricted forms provide interesting suggestions.

---

(1) Since the variance of the ith coefficient is equal to the product of the ith element of the principal diagonal inverse matrix and $\hat{\sigma}^2$ it is possible to see how the adverse effect of multicollinearity is offset by other factors in the gross output function. Comparing the net output with the gross output function, shows that the explanatory variables of intermediates and thus the inverse matrices are different. Moreover, the variable of intermediates enjoys a considerable degree of sharpness which led on the average to a $\hat{\sigma}^2$ smaller than its net output counterpart. Thus it is likely that the different inverse matrix and the small $\hat{\sigma}^2$ of the gross output functions are effective in reducing the harmful effect of multicollinearity caused by the high correlation between capital and research and development to the extent of increasing the sharpness of the coefficients of the two variables.

(c) <u>The Scottish function estimates:</u>

The estimates of the production function which introduces the input of scientists and technologists in research and development in Scottish manufacturing industries are given by table (10.2). It is to be noted that the correlation between the input of research and development and either capital or plant and machinery is 0.70 and 0.72 which is greater than its counterpart in British manufacturing industries. The effect of multicollinearity tends to reduce considerably the significance of the capital and plant and machinery coefficients rather than the significance of the coefficient of research and development in the gross output functions (10.2.4), (10.2.5), (10.2.7) and (10.2.8) while in the net output function, similar to the British sector, the significance of the research and development coefficient is the one affected. It is significant at the 30% level.

In spite of the existence of multicollinearity and in agreement with the British findings the explicit introduction of the input of research and development in the Scottish gross output function led to an explanation of a large proportion of the residual of the traditionally specified production function as follows:-

1. Comparing the unrestricted Cobb-Douglas form (10.2.4) which introduces the input of research and development, with its traditional counterpart (6.1.15), indicates that the amount explained of the residual of the former exceeds 18%.
2. Comparing the linear form (10.2.7) with its counterpart (6.1.13) shows that 36% of the residual is explained through introducing the research and development.
3. If the low significance capital is eliminated from the Cobb-Douglas form (10.2.3) and the linear form (10.2.6) while the input of research and development is left, the amount explained

Table (10.2) RESEARCH AND DEVELOPMENT PERSONNEL IN THE SPECIFICATION OF THE SCOTTISH PRODUCTION FUNCTION

Eqn. No.	Dept.	Const.	Labour		Capital		Coefficient of Plnt&machy.		R & D		Intermediates		R^2	$\bar{R}^2$
			Abst.	Log.	Abst.	Log.	Abst.	Log.	Abst.	Log.	Abst.	Log.		
1	ln. NO	2.325		0.881 (0.069)						0.0959 (0.0329)			0.931	0.924
2	ln. NO	2.222		0.774 (0.079)		0.235 (0.090)				0.0410[a] (0.0357)			0.949	0.941
3	ln. GO	1.276		0.199 (0.031)						0.0403 (0.0108)		0.741 (0.030)	0.9925	0.9913
4	ln. GO	1.348		0.198 (0.032)		0.0350[c] (0.0561)				0.0340 (0.0148)		0.716 (0.052)	0.9926	0.9911
5	ln. GO	1.367		0.203 (0.032)				0.0318[c] (0.0499)		0.0332 (0.0156)		0.715 (0.052)	0.9927	0.9911
6	G O	-1.791	0.632 (0.060)						0.0629 (0.0137)		0.116 (0.002)		0.9981	0.9978
7	G O	-2.103	0.628 (0.061)		0.0523[c] (0.0936)				0.0575 (0.0170)		0.115 (0.003)		0.9981	0.9977
8	G O	-2.146	0.633 (0.061)				0.0819[b] (0.1107)		0.0557 (0.0170)		0.115 (0.003)		0.9981	0.9977

a) significant at the 30% level b) sinificant at the 50% level c) significant at the 60% level of the residual of the traditional production functions rise to 20% and almost 39% respectively. The sharpness of the research and development coefficient rises even more than in (10.2.4) and (10.2.7).

(d) Scientific effort in the net and gross output functions:

A closer investigation of the estimated output elasticities with respect to research and development scientists and technologists, labour and capital is suggestive. In particular it is noted that the ratios of the research and development contribution to the contribution of either labour or capital in gross output function are several times larger than their counterpart ratios in the net output function in both British and Scottish manufacturing industries as follows:-

1. In British manufacturing industries the net output function (10.1.1) the percentages of the research and development contribution to the contribution of labour and capital are 5.9% and 16.2% respectively. The corresponding percentage in the gross output function (10.1.5) are 17.8% and 75.5%.
2. In the net output function for Scottish manufacturing industries (10.2.2) the two percentages are 5.5% and 17.5%. The corresponding percentages in the gross output function (10.2.4) are 17.2% and 97.1% respectively.

In view of the probable effectiveness of the multicollinearity in distorting the relative contribution of research and development to capital, the large difference which still persists between the relative contribution of research and development to labour in the gross and net output function is still indicative. Especially if the earlier finding of a sharper research and development coefficient which are recorded by the gross output viz-a-v iz net output functions is added. The two findings together suggest that it is likely that the response of the gross output to the research and development effort is stronger than net output response. Therefore it can be tentatively suggested that the findings of this study are consistent with the spill over effect of research and development effort view although the evidence is not conclusive. In other words the above findings seem to suggest that the rewards of research and development effort is unlikely to be confined to the originating industry. The technical efficiency of the average industry seems to benefit from the research and development success of other industries. At least in the form of intermediates incorporating the latest technological improvements.

(e) Scientific effort in research and development and other improvements in the production function specification.

Reference in this section will be made to the British gross output functions estimated by table (10.1). Generally speaking, the estimates indicate that the attempt to improve the specification of the aggregate production function through the explicit introduction of numbers of scientists and technologists employed in research and development is consistent with most other improvements suggested by the previous chapters. For instance introducing the research and development in addition to:-

1. Correcting for the vintage of capital (10.1.7) provided an explanation to 41.8% of the residual of the traditionally specified function (6.1.7).
2. Correcting for the level of activity (10.1.9) provides similarly 41.8% explanation of the residual.
3. Correcting for the vintage of capital and the level of activity (10.1.11) allowed 55.5% of the residual to be explained.

Further aspects of consistency are reflected by the estimates which takes into account the structure of capital and other types of improvements. However the multicollinearity is stronger in this case because the correlation between research and development and plant and machinery is greater than between the former and the stock of all fixed assets. The same applies to the modern vintages of plant and machinery and modern fixed assets. It is interesting to regard that the contribution of the modern vintages of capital and plant and machinery is still indicated greater than the contribution of average age capital and plant and machinery even if research and development is introduced in the specification of the production function. This tendency remains unaffected when combined improvements are regarded.

The findings presented above in (b), (c) and (e) indicates that the production function which excludes the input of research and development involves an error of specification which is likely to impart bias into the estimated technical efficiency as well as the coefficients of other input factors, (see Chapter XI).

CHAPTER XI

SCIENTISTS AND TECHNOLOGISTS IN THE SPECIFICATINO OF THE AGGREGARE PRODUCTIN FUNCTION

SCIENTISTS AND TECHNOLOGISTS IN THE SPECIFICATION OF THE AGGREGATE PRODUCTION FUNCTION

The intention in this chapter is to bring together the main ideas of the study, to provide a condensed summary of the findings obtained so far and to furnish further evidence with respect to the contribution of various forms of scientific and technological effort to industrial product.

In section 'A', a brief outline of the model in its general form is provided; Section 'B' summarises the results of the attempt made in Chapters VI - IX to improve the specification of capital, labour and the production function. Section 'C' is concerned with developing the theory for dealing with the various forms of scientific effort.

In Section 'D' the results of estimating the contribution of the scientific effort in research and development undertaken in Chapter X is summarised. Section 'E' investigates the lagged effect of the contribution of scientific effort in research and development.

Section 'F' reports the results of investigating the scientific effort in managerial activities. In section 'G' the contribution of scientific effort on the shop floor is investigated. Section 'H' provides general concluding remarks.

A. A brief outline of the Model:

It is advanced that the aggregate production function that expresses output as a function of the conventional factors of production tends to be inaccurately specified because:-

(i) the quality and the structure of capital and labour are often ignored,

(ii) the level of activity is not corrected for, and

(iii) the scientific effort is not explicitly introduced.

From the statistical point of view the accuracy of the specification of the aggregate production function would suffer from wrongly specifying the main input factors of labour and capital and from ignoring a correction for disequilibrium in the level of activity. Errors of specification of the aggregate production function itself and the labour and capital factors would result in serious statistical bias in the assessed parameters as well as in the measured technical efficiency (or technological progress). Such errors of specification would further lead to unsound policy recommendations. It follows that an appropriate treatment of the efforts of scientists and technologists would necessitate the use of an accurately specified aggregate production function as well as employing correctly specified factors of production. Such a production function should be modified so as to allow for assessing the contribution of scientific effort in the form that affects measured industrial product. Otherwise the assessment of technical efficiency based upon industrial product will be biased upward to the extent that output increases brought about by new products, improved processes and production technique, etc. are not attributed to their main creators.

The most probable benefits of improving the specification of the aggregate production function itself through the introduction of scientific effort and correcting for the degree of capacity utilization (as well as the accurate specification of labour and capital) are:-

(i) breaking down the residual element so as to discover strategic factors in economic growth,

(ii) reducing the aggregate bias through correcting for many inter-industry differences,

(iii) reducing the bias otherwise involved in assessing technical efficiency (or technological progress),

and therefore improving the capability of the assessed production function for policy and prediction purposes.

The attempt to avoid the above-mentioned sources of statistical bias is essential from a policy consideration point of view. Chapter V, above, considers the implications for policy of relying on less accurately specified aggregate production functions and wrongly specified factors of production. The above statistical considerations are further recommended on theoretical grounds. Owing to the obvious limitations of those models which regard technological progress as entirely of an organizational nature as well as the limitations of those models which regard technological progress as dependent upon gross investment, the present study favours a more general model. In this model it is recognised that:-

(i) some of the technical efficiency (or technological progress) is generally embodied in newly produced capital and thus a distinction is introduced between modern and old vintages of capital. In particular, some technical efficiency (or technological progress) is embodied in newly produced plant and machinery and thus a further distinction is made between plant and machinery and other types of capital structures.

(ii) Some of the technical efficiency (or technological progress) is embodied in educated, well trained and highly skilled labour, thus a distinction between various qualities and structures of labour is necessary.

(iii) A significant part of technical efficiency (or technological progress) is due to scientific effort; thus scientific effort is explicitly introduced in the aggregate production function in order to allow for the contribution of scientific effort and to reduce the bias otherwise involved in assessing technical efficiency (or technological progress). The addition to knowledge is further increased by observing a distinction between scientific effort devoted to current activities and that aimed at investment in improving future technology.

B. A Summary of Chapters VI - IX:

The traditionally specified production function was looked upon as the starting point. The efforts made to improve the suitability of the algebraic form of the production function for testing interesting hypotheses such as returns to scale, the degree of competition and the size of the elasticity of substitution are briefly regarded. Moreover, the attraction of the experimental approach in application is emphasized.

On the estimation problem, the simultaneous equation bias which is likely to affect the single equation least squares estimates is referred to. Also the views opposing the appropriateness of cross sections of inter-industry production functions in favour of micro studies and the counter-views advocating the necessity of the former for macro understanding are presented. The main limitations of the inter-industry production functions lies in the aggregate bias. It is the main occupation of the present study to reduce the aggregate bias which results from the erratic specification of the input factors and the production function itself (See Chapters V and VI). The view is put forward that the steps necessary to reduce errors of specification should preceed the attempt to deal with the simultaneous equation bias.

Five algebraic forms of the traditional production function were estimated for both the net output and gross output of the British and Scottish manufacturing industries. The estimates of the gross output function tend to support the findings of the net output function. Also the corresponding Scottish functions tend to be close to and support the estimates of the British functions.

The estimates of the restricted Cobb-Douglas form are indicated to be inferior to the estimates of the unrestricted Cobb-Douglas form. A slight suggestion of increasing returns to scale is provided by the latter form for the two sectors. However, it is statistically insignificant. Also the test of returns to scale in an inter-industry situation suffers from the arbitraness of industrial classification and the possibility that large industries may be composed of small firms and vice versa.

It seems difficult to prefer the fit of either the linear or the unrestricted Cobb-Douglas form on the other. The superiority of the two forms on the two semi log. forms is evident. Yet the satisfactory performance of the two semi log. forms may suggest that a transcendental form is likely to be acceptable on statistical and economic grounds. Application of such a function is made difficult by the relatively small number of observations available.

The consistency of the estimated output elasticities is supported generally by the close agreement of the estimates of the British and Scottish sectors with each other and with the previous studies on the U.K. Broadly speaking the labour elasticity is almost two thirds of the sum of labour and capital elasticities and the capital elasticity account for the remaining third (see Walters, 1963).

Commenting on the elasticities estimated by the traditionally specified production function, it is pointed out, is likely to be biased. The bias involved is dominantly caused by aggregate bias and partly by management bias. Chapters VI - XI are set out to deal empirically with the main sources of aggregate and management bias. In the remainder of this section a summary is made of the main steps taken to reduce the detrimental effect of aggregate bias and the results of application. The effect of the explicit introduction of scientific effort in improving the specification of the aggregate production function will be presented by sections D - G.

(a) Improving the specification of capital via a distinction between modern and old vintages.

Although two dimensions are known of capital quality, viz. the rate of technical improvements in capital goods industries and the vintage of capital, only the latter enjoyed application in practice. It is emphasized that an estimation of the aggregate production function which disregards the vintage of capital involves a mis-specification of the input of capital that is likely to result in biasing the estimated technical efficiency (or technological progress) as well as the estimated parameters of the aggregate production function.

The difficulty of getting data sufficient for comprehensive application of the vintage models resulted in a limited application of theory in practice so far. It involved regarding the vintage of capital through estimating production function for a cross-section of plants whose vintage is the same. It is known as a modified vintage production function since the age of capital is regarded implicitly through considering the output producable by a certain vintage of capital and the labour operating this capital.

A method is introduced in order to draw a distinction between only two vintages of capital because of the limitations of existing data. Gross investment net of depreciation is integrated for each type of capital over a period of seven years in order to estimate modern stock capital. Older types of capital stock are estimated by integrating gross investment net of depreciation and retirement over the rest of the life span of each type of capital. The estimated aggregate production function which incorporates the two vintages of capital showed that the contribution of the modern capital is on the average 40.7 per cent more than the contribution of the average age capital. Most interesting is the finding of a significant and negative contribution of older vintages of capital which is consistent with the mainly empirical view adopted by some industrialists which is the older vintages of capital stand as a heavy burden in the way of industrial growth and efficiency.

Moreover, correcting for the vintage of capital allowed on the average 47 per cent of the residual of the traditionally specified production function to be explained and led further to a considerable increase in the sharpness of labour coefficient, (to the standard error), from 13.1 times in the traditional function to 17.3 times in the above function.

The following concluding remarks are thus suggested:-

(i) A serious bias is likely to be involved in assessing the technical efficiency and/or the coefficients of the production function if no distinction is drawn between various layers of capital vintages.

(ii) that if capital formation is allowed to proceed at a high rate such as to alter the balance in favour of modern capital, then a considerable increase in the efficiency of capital, industrial growth and technical efficiency are likely.

(iii) that in forecasting or planning full employment output for a future date, a measurement of capital that ignores a distinction between high quality and low quality may result in under-estimating the potential full employment output if capital formation proceeds at a rate faster than the one experienced during the period used in forecasting and vice versa.

(b) Improving the specification of capital via:-

(i) a distinction between various structures of capital and, in particular, plant and machinery and other structures,

and

(ii) a combined distinction between capital's structures and vintages.

An earlier attempt to establish a distinction between three types of capital structure, namely, plant and machinery, buildings, and vehicles, was faced by multicollinearity, mainly because of the high correlation between various structures of capital. Then a distinction between plant and machinery and other structures of capital was adopted as an alternative.

The estimates of net output and gross output functions, in which a distinction is drawn between plant and machinery and other infra-structures, for British and Scottish manufacturing industries are all affected by multicollinearity. Yet, in most cases it is found that the sum of the estimated elasticities of the two types of capital structure are close to the estimated elasticity of all fixed assets. This consistency indicates that the multicollinearity is not detrimental to the estimates of the elasticities of capital structures.

A higher significance and a considerably greater output elasticity with respect to plant and machinery (exceeding 2.7 times) vis-à-vis other capital structures is also found which may suggest:-

1. that a measurement of capital which ignores a distinction between various types of capital involves a mistaken specification that may result in an overstatement of the level of the estimated technical efficiency (See Section 'B' of Chapter V).

2. that a planned full employment level of output for a future date which is based on extraprolating capital requirements ignoring the structure of capital, is likely to be understated if the rate of forming plant and machinery overtakes the rate of accumulating other types of capital.

Furthermore, the lesser capacity to contribute, combined with the lower level of significance of the infra-structure coefficient is noteworthy. From a statistical measurement point of view, the ability of the plant and machinery variable to be representative of the capital factor is improved by excluding the infra-structure variable. The explanatory power of this production function exceeds that of the traditionally specified function which measures capital by the stock of all fixed assets. It thus seems likely that the explanatory power of capital as a whole is derived mainly from the plant and machinery component. Therefore, it may be reasonable to advance the view that even in the absence of significance of other types of capital, plant and machinery is by and large a better representative of the contribbution of capital to output than is total capital.

It is found that an increase in the degree of disaggregating capital is limited by the increase in the effect of multicollinearity. In order to investigate the combined effect of correcting for the structure and vintages of capital two equations are regarded with respect to British manufacturing industries. In the first, capital is disaggregated into modern vintages of plant and machinery and the rest. Alternatively other structures of capital were excluded and a distinction is made between modern and older vintages of capital. The findings indicated by estimating either functions are consistent with each other. The former indicates that:-

1. the output elasticity with respect to modern plant and machinery is statistically significant, and on the average 41.9% larger than the average age plant and machinery. The output elasticity of the rest of capital (i.e. all fixed assets minus modern vintages of plant and machinery) is negative and has low level of significance. This finding is consistent with the previous finding with respect to modern and older vintages of capital and supports the view that older vintages of capital (and particularly of plant and machinery) is a handicap for industrial progress and efficiency.
2. The combined correction for the structure and vintages of capital allowed on the average 20% explanation of the residual of the traditionally specified production function. This finding and the preceeding one support the view that a measurement of capital which ignores the distinction between various vintages of various structures is likely to impart an upward bias in the estimated technical efficiency.

(c). Improving the specification of the aggregate production function through allowing for disequilibrium in the level of activity.

In spite of the fact that the measure of the degree of capacity utilization employed viz. the ratio of employees in employment to insured employees, suffers from theoretical limitations, yet the results of the empirical application are revealing.

(i) The general conclusion which can be derived from the estimates of Chapter VIII for British manufacturing industries are:-

1. It seems highly unlikely that the British industries did adjust themselves to the prevailing phase of trade cycle in 1962. This is suggested by the significance of the coefficient of the degree of capacity utilization at the 1 per cent level whether the production function explains net output or gross output. It is interesting to note that the significance of the coefficient of the degree of capacity utilization is left unaffected when corrections are made for the structure of capital, for the vintage of capital or for a combination of both.
2. The significance of the coefficient of the degree of capacity utilization is not affected by the form of the production function used. The linear and the Cobb-Douglas forms which explain net output and gross output indicate that the coefficient of the degree of capacity utilization is significant at the 1 per cent level.
3. The introduction of the level of activity in the specification of the aggregate production function allowed on the average a 30 per cent of the residual of the traditional specification of production function to be explained.
4. The output elasticity with respect to the degree of capacity utilization is on the average greater than six times the sum

of the two elasticities of labour and capital, in particular, at the level of activity prevailing in 1962.

It is, however, unlikely that such a high elasticity will be estimated at other levels of activity. It is likely that the ratio used to measure the level of activity here is partly responsible for reflecting such a high degree of output response to the level of activity.

Moreover, it may be that the variable used to measure the degree of capacity utilization stands as a catch-all for other influential factors which are not allowed for such as the scale of operation. It is known that the labour productivity is strongly affected by the degree of capacity utilization. What the present evidence suggests is that the technical efficiency is likely to be influenced to a large extent by the level of activity.

5. The reflected considerable response of the flow of output to the degree of capacity utilization seems to suggest profound policy implications. Broadly speaking the supply side seems to require consideration more than what is being given at present in managing the economy.

6. The introduction of the degree of capacity utilization does not only increase the explanatory power of the production function but also leads to an improvement in the sharpness of the coefficients of labour and capital. In short it may be regarded as essential to improving the specification of the aggregate production function.

Correcting for the degree of capacity is thus indicated to have the virtue of reducing the statistical bias involved in the mistaken specification of the aggregate production function in the particular case when the equilibrium assumption may not apply for the considered industries. This bias is likely to result in distorting the assessment of technical efficiency, the output elasticity with respect to labour, and the elasticity with respect to capital. It may be added that the degree of capacity utilization is most useful in correcting for the mis-specification of labour and capital in the production function especially when either or both are represented by a measurement of stocks rather than a service flow for which less information is available.

(ii) Chapter VIII gives also the estimates of the production function which is corrected for the level of activity for Scottish manufacturing industries net output and gross output which indicate that:-

1. A considerable response is reflected for the flow of output to the degree of capacity utilization. The estimated output elasticity with respect to the level of activity is close to that estimated for British manufacturing industries which may be regarded as a sign of the consistency of the data estimates for Scottish manufacturing industries. It is to be noted, however, that the significance of the coefficient of the degree of capacity utilization is achieved only at the 10 per cent level.
2. In spite of the low significance of the coefficient of the degree of capacity utilization, a correction for the level of activity allowed on the average for an 8 per cent and 7 per cent explanation of the residual. Moreover, the sharpness of the labour and capital coefficients has improved due to correcting for the level of activity.

It is likely that the ratio used for measuring the degree of capacity utilization becomes less representative of the actual capacity utilization when applied to Scottish manufacturing industries than in the case for British manufacturing industries because of the clear indication of chronic unemployment in the majority of Scottish manufacturing industries over the 13 months preceeding June of the year of investigation in 1962.

(d) Improving the specification of labour through a distinction between males and females.

In the applications of chapters VI - VIII, the homogeniety of labour is implicitly assumed. Since this assumption is unrealistic it has to be relaxed. Age-sex composition, skill, education, etc., in short structural and qualitative aspects of labour vary from one firm to another and from one industry to another. The sex structure of the employed labour is regarded in chapter IX for British and Scottish manufacturing industries. The quality of labour is regarded in the following chapters X and XI through drawing a distinction between scientists and technologists and other labour.(1)

---

(1) It is also to be noted that it is evident that the contribution of labour towards the productive activity is largely a function of the level of education and training (general and specific), they received as well as the experience they gained. Given the available data on an industry level up to 1962 it was not possible to introduce a correction for the level of education though it would have been preferable to do so. Unless a direct relationship can be assumed between the level of education an industry requires and the number of qualified scientific manpower she employes, no correction for the level of education can be claimed. Though such an assumption is appealing in the sense that an industry which is a large employer of qualified scientific manpower seems likely to have a special appetite to highly trained labour to ensure a smooth communication and capability in applying the developed and improved techniques, ideas, processes and products. This is suggested by finding an extremely high correlation between the number of qualified scientific manpower in research and development and the supporting staff in industry (the data **is** provided by the third triennial survey of scientific and technological manpower in Great Britain). Nevertheless, no such assumption is adopted and the limitation of the lack of correction for the level of education is emphasized. It is, moreover, recommended that the level of education must be regarded, data permitting, in future research.

It is emphasised that ignoring the heterogeneiety of labour involves a wrong specification which is likely to introduce bias in the estimated technical efficiency as well as in the estimated coefficients of other input factors. Also it is pointed out that there are dangers on relying on wrongly specified function in projecting the amount of resources necessary to achieve certain levels of activity at a future date.

Drawing the distinction between male and female employees in the net output and gross output functions of British and Scottish manufacturing industries indicated that:-

Firstly: there is a large and statistically significant difference between the males and females elasticities. The contribution of males is on the average 2.4 and 2.8 times as large as the females elasticity in British and Scottish manufacturing industries respectively.

The large difference between the contribution of males vis-a-vis females in British manufacturing industries is consistent with the large difference between the average weekly earnings of males and females in all British manufacturing industries. The average weekly earnings in the second pay week in April 1962 for the full time adult male (21 years and over) is almost 2.1 times its counterpart for full time adult females (18 years and over).[1]

It is to be noted, moreover, that the estimated difference enjoys a considerable stability even when other improvements in the specification of the aggregate Production function are introduced.

However, the true difference between the males and females contributions is most likely to be less than the estimated difference in view of the a priori grounds:-

---

(1) Ministry of Labour Gazette "Earning and Hours in April, 1962", Vol. 70, No. 8, Aug, 1962 pp. 295 - 303.

1. The monthly statistics of labour do not distinguish between part-time and full-time employees and it is known that females are concentrated in part-time jobs more than males.

2. The average weekly hours of full time adult males (21 years and over) is longer than the average weekly hours of full-time adult females (18 years and over). In the second pay week of April, 1962 in all British manufacturing industries sector these are 46.6 and 39.4 hours respectively.

Leaving out of consideration the average hours worked by males and females, the number of employees is likely to over-estimate the flow of females services relative to the flow of male services and, consequently under-estimate the relative contribution of females vis-à-vis males towards the production processes. An evaluation of the likely bias is not attempted by this study.(1)

Secondly: regarding the distinction between males and females in the specification of the aggregate production function has led on the average to explaining 18% and 8% of the residual of the traditionally specified net output function of British and Scottish manufacturing industries respectively. Moreover, the percentage explained of the residual reflected a steady increase according to the number of other improvements introduced to the specification of the aggregate production function and the other factors of production (see Chapter IX).

The implication of these findings, from an econometric point of view, is revealing; it indicates the necessity for taking account of the structural aspects of labour, if a more accurate specification of the labour factor in the production function is to be achieved, as well as if the bias otherwise involved is to be avoided. The main source of bias is

---

(1) A simple correction for the ratio of male to female earnings according to the length of hours worked per week indicate that the ratio of overage hourly earnings is almost 1.7.

the considerable and statistically significant difference between the output elasticities with respect to males and females and the considerable stability of the estimated difference. Also, these findings support the fears expressed earlier with respect to relying on less accurately specified production functions and input factors in projecting the amount of resources necessary to achieve certain planned levels of activity at a future date.(1)

---

(1) There is, however, one more aspect of the implication of this finding in practice. The aggregate production function is a tempting tool for the comparison of inter-industry efficiency as well as inter-temporal technological progress. By ignoring the structure of labour, the relative Technical Efficiency of those industries which employ more females will be biased downwards and of those who employ mainly males will be biased upwards (even if part-time employees are counted with greater accuracy).

C. Scientific Effort: Theory:

The contribution of scientists and technologists used to be treated as an indistinguishable part of technological progress. When it was realised that breaking down the third factor is a sound means of discovering strategic factors in economic growth, interest was then directed (among other things), at inventive - innovative activities. The numbers of patents and successful major inventions were two familiar candidates in studying the results of inventive-innovative activities. On the input side research and development expenditures and research and development personnel attracted most of the attention. Those studies which relied on research and development personnel recognised that the qualified scientific manpower is the dominant factor in the inventive-innovative process and that their creative ability is best in the fields they are most familiar with. The presumptive association between fields of inventions and innovations and the degree of familiarity suggests the possibility of a positive association between the industrial distribution of research and development personnel and the output of inventive-innovative activities.(1)

Two main points are worth noting with regard to that approach. The first is that amongst the scientific base, only research and development personnel appears to have acquired much interest. Even so, no distinction was made between Qualified Scientific Manpower and the supporting staff. The second point is that in this analysis it is implicitly assumed that creative men tend to be randomly distributed

---

(1) It is to be noted that creative individuals are likely to prefer newer and therefore, more interesting fields. Similarly such funds as may be needed to finance inventive-innovative activity are likely to be more readily available for projects which the suppliers of the funds can appreciate.

among the main scientific functions.(1) Neither point is in line with this present analysis.

The line taken by this study in dealing with the effort of scientists and technologists is to assess the relative contribution of each one of three main scientific functions within the framework of productive activities. Due regard is thus given to a distinction among three main selected activities of scientists and technologists in manufacturing industries. These are, research and development effort, on-the-shop-floor activities, and scientific management.(2)

It is obvious that the three types of effort differ in the nature of work carried out, in the activity towards which the effort is directed which is in turn affected by resource allocation between current productive activities and investment in improving technology, and in the length of time period during which scientific effort pays off (See Section E).

The employment of Qualified Scientific manpower on research and development is the main factor of scientific effort devoted mainly to attaining a technical lead or catching up with technical leaders. Thus, the inventive-innovative effort of the research and development personnel is regarded as one of the main components of investment devoted to improving technology. However, a wider scientific base is needed to support research and development effort. Innovations may reach the commercial production stage more rapidly if there is a sufficient number of Qualified Scientific Manpower on-the-shop floor able to link the

---

(1) See E. G. Schmookler and Brownlee, 1962. p.166.

(2) If economic rather than productive activities were the framework chosen to investigate the effectiveness of scientists' and technologists' effort, other scientific functions such as sales and after-sales services, scientific function should have been added. If the study exceeds theindustrial sector to the national level the education function is an additional candidate.

research and development department with the production department to appreciate research and development output and to manage its application. Scientifically appreciative management is also essential for directing and co-ordinating the scientific effort, assessing commercial growth potential of a given invention and/or a research and development project. They are best informed of the marketable capital equipment, fuel and components that incorporate the latest know-how. Also they are invaluable in establishing links with other leaders in the field.

It may also be advanced that the effort of Qualified Scientific Manpower on-the-shop floor is the main component of current scientific effort aimed at current productive activity. It may also be that part of the effort of scientific management as well as research and development personnel at a given time period can be regarded as contributing to the production of the same time period.

The attempt made above (see Section B), to improve the assessed parameters of the aggregate production function may be regarded as necessary yet not sufficient. The view is advanced above that a measurement of technical efficiency based on industrial product will be biased upward to the extent that output increases brought about by scientific effort are not attributed to their main creator. It is also a cause for concern that the inaccuracy in the specification of the aggregate production function which results from leaving out of consideration scientific effort may well impart a bias in the assessed coefficients of labour and capital.

The bias involved in assessing technical efficiency as well as the production function parameters due to ignoring scientific effort may be briefly attributed to:-

(a) an error of specification of labour: since scientists and technologists are components of manpower, then a failure to distinguish between qualified personnel and the rest of employees (as well as amongst various structures and qualities of other employees) will bias the assessed technical efficiency as well as the assessed parameters of the aggregate production function to the extent that there is a significant difference between the contribution of various types of manpower.

(b) an error of specification of the aggregate production function: to the extent that scientists and technologists are effective contributors to the productive process, then a failure to incorporate scientific effort as a separate factor of production tends to render the production function less accurately specified via allowing other input factors, and in particular the third factor, to stand as a catch-all for their contribution.

(c) an error of specification of capital: scientists and technologists are the innovators of newly produced capital that embodies the latest know-how; in addition they are likely to be an influential element in increasing the efficiency of modern equipment's utilization in industry. As a consequence, if scientific effort is ignored in specifying the aggregate production function, the assessed coefficient of capital will probably be biased to the extent that it has to represent partly the contribution of a missing yet particularly influential factor of production. It may be necessary to add that this bias may not be eliminated by taking into account the vintage of capital; probably the bias will affect the parameters of the modern rather than older layers of capital.

As will be seen below, one of the virtues of increasing the accuracy with which the aggregate production function is specified through the introduction of scientific effort is to decrease the residual, i.e. to improve the assessed technical efficiency or technological progress and to improve the assessed parameters of labour and capital. However, "the addition to our knowledge" seems to be greater if a further distinction among various components of scientific effort is observed.

A measurement of scientific effort which regards only total employment of scientists and technologists ignores well known theoretical aspects such as:-

(a) the elements of risks and uncertainty, (which are most profound at firm level): These are characteristics of research and development effort more than on-the-shop floor and probably other functions of scientific effort.

(b) the decision to undertake a research and development project or programme is mainly a decision to allocate resources away from current production to investment in improving future technology. In other words it makes it possible in the future to use same amount of resources (currently used) to produce more output or use less resources to produce a given output. On the other hand scientific effort on-the-shop-floor cannot conceivably be regarded as directed, even partly, to other than current production activities.

(c) It is another characteristic of research and development effort that a given innovation rarely pays off for the resources employed in its achievement instantaneously or in a period as short as one year. It follows that the contribution of research and development to industrial product is spread over more than one period of time perhaps in a distributed lag form. On the other hand it seems highly likely that scientific effort on-the-shop-floor contributes to the productive process without delay. Scientific management is an influential element in the success of inventive-innovative activities. However, it is equally responsible for the productiveness of scientific effort on-the-shop floor. It is thus highly likely that a given part of scientific management effort shares with research and development the elements of risk and uncertainty as well as the sense of devotion to improving future technology.

D. The contribution of Scientific Effort in Research and Development:

In this section it is intended to investigate the contribution of current research and development effort to current productive activities. The likelihood of a simple lag or a family of lags which contributes to a given productive process is regarded in section (E).

The high correlation between scientists and technologists in research and development and various forms of capital produced multi-collinearity which tended to affect the sharpness of either the research and development coefficient or the capital coefficient. The distortion caused by multicollinearity is found to be most effective in the case of the estimates of the Cobb-Douglas net output function and almost harmless for the estimates of the linear form of gross output function of British manufacturing industries. In spite of the existence of multicollinearity, the estimates are revealing. The main findings of Chapter X are:-

Firstly: improving the specification of the production function through the introduction of the input of research and development, the estimates of the British function indicate that:-

1. In spite of the finding that the coefficient of research and development is significant at the 10% level, (other coefficients are significant at the 1% level), in the Cobb-Douglas net output function, the introduction of research and development provided on the average 15% explanation of the residual of the traditionally specified production function. If research and development expenditure is used instead of research and development personnell in the Cobb-Douglas net output function, the correlation of the former with capital being 0.51 is lesser than the correlation between capital and research and development personnel, the sharpness of research and development coefficient is increased to become significant at the traditional 5 per cent level and the percentage explained of the residual rose to 16 per cent.

2. the multicollinearity in the unrestricted Cobb-Douglas form explaining gross output produced a large decrease in the sharpness of the capital coefficient which can only be significant at the 30% level but indicated the coefficient of research and development to be significant at the 1% level. In spite of that the percentage explained of the residual of the traditionally specified production function due to the introduction of research and development reached 28.5%.
3. in the linear production function explaining gross output, for instance, all the coefficients are significant at least at the 2% level. The percentage explained of the residual due to the introduction of scientific manpower in research and development reached 25%.

In Scottish manufacturing industries, the correlation between the input of research and development and either capital or plant and machinery is greater than its counterpart in British manufacturing industries. The effect of multicollinearity tends to decrease considerably the significance of the capital and plant and machinery coefficients rather than the significance of the coefficient of research and development in the gross output functions while in the net output function the significance of the research and development is achieved at the 30% level.

In spite of the existence of multicollinearity and in agreement with the British findings the explicit introduction of the input of research and development in the Scottish gross output Cobb-Douglas and linear functions led to an explanation of 18% and 36% of the residual of the corresponding traditionally specified production functions respectively.

Thus, the findings in both the British and Scottish manufacturing industries indicate that the production function which excludes the input of research and development involves an error of specification which is likely to impart bias to the estimated technical efficiency and the coefficients of other input factors.

Secondly: a closer investigation of the estimated output elasticities with respect to research and development scientists and technologists, labour and capital is suggestive. In particular it is noted that the ratios of the research and development contribution to the contribution of either labour or capital in gross output function are several times larger than their counterpart ratios in the net output function in both British and Scottish manufacturing industries. Even if it is accepted that the large difference between the ratios of the contribution of research and development and capital is affected by multicollinearity, the large difference which still persists between the relative contribution of research and development to labour in the gross and net output function is still indicative. Especially if the earlier findings of the sharper research and development coefficient which are recorded by the gross output viz-a-viz net output functions are recalled. The two findings together suggest that it is likely that the response of the gross output to the research and development effort is stronger than net output response. Therefore it can be tentatively suggested that the findings of this study are consistent with the spill over effect of research and development effort view although the evidence is not conclusive. In other words the above findings seem to suggest that the rewards of research and development effort are unlikely to be confined to the originating industry. The technical efficiency of the average industry seems to benefit from the research and development success of other industries.

Thirdly: regarding Scientific effort in research and development with other improvements in the production function specification is suggestive. The estimates of gross output functions indicate that the attempt to improve the specification of the aggregate production function through the explicit introduction of numbers of scientists and technologists employed in research and development is consistent with most other improvements suggested by the previous chapters. For instance introducing the research and development in addition to:-

1. Correcting for the vintage of capital provides an explanation to 41.8% of the residual of the traditionally specified function.
2. Correcting for the level of activity provides similarly 41.8% explanation of the residual.
3. Correcting for the vintage of capital and the level of activity allowed 55.5% of the residual to be explained.

Further aspects of consistency are reflected by the estimates which takes into account the structure of capital and other types of improvements. However, the multicollinearity is stronger in this case because the correlation between research and development and plant and machinery is greater than between the former and the stock of all fixed assets. The same applies to the modern vintages of plant and machinery and modern fixed assets. It is interesting to regard that the contribution of the modern vintages of capital and plant and machinery is still indicated greater than the contribution of average age capital and plant and machinery even if research and development is introduced in the specification of the production function. This tendency remains unaffected when combined improvements are regarded.

A closer consideration of the output elasticity with respect to capital and output elasticity with respect to research and development seems to be suggestive. It is noted that the sum of the two coefficients is close to the elasticity of capital alone in the traditionally specified production function. Table (11.3) summarises the estimates of the estimated elasticities for British manufacturing functions. The estimated

Table (11.1) THE CORRELATION COEFFICIENTS BETWEEN SCIENTISTS AND TECHNOLOGISTS AND CAPITAL IN 1962

	R & D SMI	R & D BMI	On-the-shop-floor	Managl & Others	Total
All fixed assets	.70	.60	.71	.62	.64
All plant & machy.	.72	.64	.75	.66	.68
Modern assets		.64	.74	.64	.68
Modern plant& machy.		.67	.77	.67	.71

Table (11.2) THE CORRELATION MATRIX FOR VARIOUS TYPES OF SCIENTIFIC EFFORT

	R & D 1962 (1)	On-the-shop floor (2)	Managl.& others (3)	Total scientists and technologists (4)	R & D 1959 (5)	R & D 1956 (6)
(1)	1	.92	.92	.98	.97	.96
(2)		1	.77	.98	.93	.88
(3)			1	.96	.93	.88
(4)				1	.97	.93
(5)					1	.96
(6)						1

Table (11.3) THE EFFECT OF INTRODUCING SCINTIFIC INPUT IN THE PRODUCTION FUNCTION ON THE ESTIMATED OUTPUT ELSTICITY WITH RESPECT TO CAPITAL

Eqution No.	Dept.	Elsticity of output with respect to: Allffixed assets	R & D Personnel 1962	R & D Personnel 1956	R & D Expends. 1962	R & D Expends. 1956	On-the-shop floor personl. 1962	Sumofthe elsticities of capital & scietc. input	$\bar{R}^2$	The likely overstatement of capital elasticity
(6.1.4)	ln.NO	0.324							0.962	
Compared with										
(10.1.1)	"	0.272	0.0440 [a]					0.316	0.966	19.1%
(11.4.2)	"	0.262		0.0491				0.311	0.329	23.7%
(11.4.7)	"	0.280			0.0486			0.329	0.968	15.7%
(11.4.6)	"	0.262				0.0477		0.310	0.968	23.%
(11.4.5)	"	0.256					0.663 [b]	0.322	0.966	26.7%
(8.1.6)	in.G O	0.140							0.9894	
Copared with										
(11.417)	"	0.098		0.0254				0.124	0.9912	41.8%
(11.4.19	"	0.107					0.0317 [b]	0.139	0.9902	30.0%

a) significant at the 10% level , b) significant at the 20% level coefficients given in that table are significant at least at the 20% level. These estimates indicate that capital elasticity which is estimated by the traditionally specified production function is likely to be overstated as a result of ignoring scientific effort from the specification of the production function.

It is to be noted that the overstatement of capital elasticity is indicated by the estimates of the production functions which corrects for either current or laged research and development personnel or expenditures.

Moreover, the upward bias in the estimation of capital elasticity is indicated even if a correction for capital structure and/or vintage and for the degree of capacity utilization is regarded.

This finding, which is supported by sections F - H, is consistent with the view that ignoring scientific effort in the specification of the production function is likely to impart a bias in the estimated coefficients of the production function.

E. Simple versus distributed lag of research and development contribution.

There is wide acceptance of the opinion that there are lags between industrial research and development effort, innovation results if any, and subsequent embodiment in capital equipment and/or organizational change. Thus, research and development effort may be related to industrial product with a lag. However, on theoretical grounds, it is more likely that a distributed lag of research and development effort is suitable for the sector of manufacturing industries. At a certain point of time it is likely that some of the results of research and development may be in the rising phase for some industries while for others they may be in the diminishing phase. Moreover, some gains from research and development effort are slow and take a long time to be exhausted for some industries (e.g. aircraft), while for others they are almost instantaneous and may render most of their benefit within a short period (e.g. drugs). Moreover, the process of research and development with regard to a new product or process does not, in practice, come to an end even after the stage of commercial launching, since further effort is needed to improve quality and to discover new ways of application.

The determination of a distributed lag in research and development, if there is suitable data for a sufficient length of time, may follow a trial and error approach. In other words, various lag structures and orders may be experimented with in order to find the one which behaved in the best manner. Unfortunately, the data available on research and development effort carried out by British Manufacturing industries is insufficient to permit a lag specification. The number of scientists and technologists in research and development are available through the triennial surveys of Scientific and Technological Manpower in Great Britain. In order to make use of this data for the purpose of this study, a laborious effort was undertaken to obtain an otherwise absent comparability between research and development personnel of the three relevant years (i.e. 1956, 1959 and 1962).(1)

In addition to the data problems, there is also the problem of multicollinearity which resulted from an extremely high correlation amongst research and development personnel of the three years. The correlation matrix is shown by Table (11.3). A change from a simultaneous treatment of a (three years) distributed lag to a simple lag assessment became thus a necessity.

The incorporation of the research and development effort undertaken at three discreet time periods in the same aggregate production function could be used to serve two purposes. The first is to provide an assessment of the relative contribution of research and development undertaken at three different times. The second is to obtain estimated rather than arbitrary weights to combine the three research and development efforts in a special form of a distributed lag. That multi-collinearity prevented the realization of such purposes is not surprising in view of the high correlation amongst research and development personnel over the survey years.

In spite of the above difficulties and qualifications, the evidence obtained, though indirect and tentative, seems to be consistent with the view advanced which favours a distributed lag rather than a simple lag. In order to avoid the above source of multicollinearity each research and development effort is introduced singularly into the specification of the aggregate production function. The estimates of the Cobb-Douglas net output function which introduces research and development effort undertaken in 1956, 1959 and 1962 are provided by (11.4.2), (11.4.1) and (11.4.4) respectively. The corresponding estimates of the gross output function are given by (11.4.10), (11.4.9) and (11.4.12). In consistency with the earlier remarks that multicollinearity caused by the high correlation

---

(1) For the main sources of heterogeneity and the methods used to arrive at temporally comparable figures, See Chapter IV.

Table (11.4) The introduction of various forms of scientific effort in sp
of British Manufacturing Industries.

Eqn. No.	Dept.	Constant	Labour	Capital All	Capital Modern	Degree of capacity utilization	Research and Development 1956	Research and Development 1959
1	lnNO	2·060	0·744 (0·054)	0·279 (0·055)				0·0400[b] (0·0244)
2	-	2·111	0·747 (0·052)	0·262 (0·053)			0·0491 (0·0212)	
3	-	2·105	0·730 (0·056)	0·295 (0·056)				
4	-	2·081	0·741 (0·054)	0·272 (0·055)				
5	-	1·992	0·743 (0·053)	0·256 (0·062)				
6	-	2·371	0·744 (0·052)	0·262 (0·053)			0·0477* (0·0217)	
7	-	2·288	0·731 (0·052)	0·280 (0·050)				
8	-	1·970	0·740 (0·054)	0·268 (0·057)				
9	lnGO	1·501	0·231 (0·030)	0·0744[b] (0·0495)				0·0339 (0·0140)
10	-	1·561	0·232 (0·029)	0·0735[b] (0·0469)			0·0334 (0·0122)	
11	-	1·564	0·220 (0·032)	0·0903[b] (0·0530)				
12	-	1·464	0·228 (0·029)	0·0538[c] (0·0493)				
13	-	1·539	0·231 (0·032)	0·0851[b] (0·0537)				
14	-	1·755	0·231 (0·030)	0·0776[b] (0·0474)			0·0324* (0·0125)	
15	-	1·690	0·222 (0·029)	0·0849[a] (0·0445)				
16	-	1·430	0·228 (0·030)	0·0686[c] (0·0519)				
17	-	1·708	0·226 (0·026)	0·0981 (0·0438)		3·357 (1·498)	0·0254 (0·0116)	
18	-	1·669	0·225 (0·027)	0·0986 (0·0450)		3·619 (1·490)		0·0263 (0·0128)
19	-	1·710	0·225 (0·028)	0·107 (0·048)		3·958 (1·530)		
20	-	1·729	0·216 (0·028)	0·111 (0·047)		4·020 (1·526)		
21	-	1·907	0·217 (0·023)		0·123 (0·034)	3·269 (1·250)	0·0169[b] (0·0103)	
22	-	1·886	0·216 (0·023)		0·125 (0·034)	3·446 (1·237)		0·0174[b] (0·0112)
23	-	1·944	0·215 (0·024)		0·137 (0·037)	3·693 (1·279)		
24	-	1·943	0·210 (0·024)		0·135 (0·035)	3·696 (1·261)		

* Coefficient of research and development expenditures
a Significant at the 10% level

... specification of the production function

... the log of ... -the-shop-floor	Scientific management etc	Total Scientists & technologists	Intermediates	R^2	$\overline{R}^2$
				0·970	0·965
				0·993	0·969
	0·0329[c] (0·0314)			0·968	0·963
0·0440[a] (0·0346)				0·971	0·966
·0663[b] (·0385)				0·970	0·966
				0·973	0·968
0·0086* (0·0102)				0·973	0·968
		0·553[a] (0·317)		0·971	0·966
			0·660 (0·046)	0·9906	0·9886
			0·655 (0·044)	0·9912	0·9893
	0·0318[b] (0·0187)		0·653 (0·050)	0·9893	0·9869
0·0406 (0·0149)			0·675 (0·045)	0·9916	0·9897
·0406[a] (·0229)			0·641 (0·048)	0·9894	0·9871
			0·651 (0·044)	0·9909	0·9889
0·0351* (0·0126)			0·655 (0·044)	0·9913	0·9894
	0·0434 (0·0187)		0·661 (0·047)	0·9904	0·9883
			0·638 (0·041)	0·9932	0·9912
			0·642 (0·042)	0·9930	0·9910
·0317[b] (·0203)			0·627 (0·042)	0·9924	0·9902
	0·0256[b] (0·0164)		0·635 (0·044)	0·9924	0·9902
			0·618 (0·033)	0·9951	0·9937
			0·620 (0·033)	0·9950	0·9936
·0151[c] (·0181)			0·608 (0·034)	0·9946	0·9930
	0·0149[c] (0·0141)		0·613 (0·034)	0·9947	0·9931

...t at the 20% level
...t at the 30% level and over.

Table (11.5) Introducing Scientific effort in research and

Equn. No.	Dept.	Constant	Labour	Research and Devlt. 1956	1959	1962
1	lnNO	2·260	0·916 (0·064)		0·102 (0·032)	
2	-	2·346	0·903 (0·061)	0·105 (0·028)		
3	-	2·387	0·888 (0·072)			
4	-	2·299	0·898 (0·063)			0·108 (0·031)
5	-	2·008	0.870 (0·060)			
6	-	2·929	0.895 (0.061)	0.104* (0.027)		
7	-	2·784	0·903 (0·067)			0·099* (0·032)
8	-	2·001	0·887 (0·063)			
9	lnGO	1·316	0·242 (0·030)		0·0454 (0·0122)	
10	-	1·397	0·244 (0·031)	0·0429 (0·0119)		
11	-	1·353	0·227 (0·034)			
12	-	1·334	0·233 (0·028)			0·0497 (0·0113)
13	-	1·333	0·243 (0·032)			
14	-	1·642	0·241 (0·030)	0·0427* (0·0112)		
15	-	1·531	0·232 (0·030)			0·0456* (0·0120)
16	-	1·241	0·236 (0·030)			

* Coefficient of Research and Development expenditures.

development into the production function which excludes capital.

On the shop floor	Managerial etc.	Total Scients.	Inter-mediates	R^2	$\bar{R}^2$
				0·929	0·922
				0·936	0·930
	0·113 (0·042)			0·921	0·913
				0·933	0·927
0·169 (0·038)				0·944	0·938
				0·938	0·932
				0·927	0·919
		0·139 (0·038)		0·936	0·929
			0·716 (0·029)	0·9894	0·9878
			0·708 (0·030)	0·9891	0·9875
	0·0492 (0·0165)		0·720 (0·031)	0·9876	0·9856
			0·715 (0·027)	0·9910	0·9896
0·0613 (0·0196)			0·697 (0·033)	0·9880	0·9861
			0·707 (0·029)	0·9896	0·9879
			0·721 (0·029)	0·9896	0·9879
		0·0579 (0·0154)	0·711 (0·029)	0·9895	0·9877

between capital and research and development personnel, tends to affect the sharpness of the research and development coefficient in the net output function and the capital coefficient in the gross output function. The respective levels of significance for the research and development coefficients are 5%, 20%, and 10% and the levels of significance of the coefficients of capital in the gross output functions are 20%, 20% and 30%. If the capital variable is removed all the coefficients of research and development of the three years becomes significant at the 0.1% level, (see equations (11.5.2), (11.5.1), (11.5.4), (11.5.10), (11.5.9) and (11.5.12) respectively).

It is to be noted that the significance of the coefficient of research and development expenditures for the years 1956 and 1962 at the 5% level is achieved in the Cobb-Douglas net output function. The correlation between research and development expenditures and capital, it is to be recalled, is smaller than between capital and research and development personnel.

The above estimates seem to be consistent with, rather than providing enough evidence to, the view that research and development tends to contribute to industrial production in the form of a distributed lag.

F. Scientific Management:

The previous attempts to "free" the production function assessment from management bias (as well as to reduce simultaneous equation bias) was pioneered by Mundlak (1961) and Hoch (1962) through pooling time series and cross-section data and using the analysis of covariance to obtain consistent coefficients of the production function. Hoch, e.g., introduced a farm dummy variable, a temporal dummy variable in addition to the general constant term.(1) The farm dummy variable is used to assess the management contribution in the technical efficiency of the farm. However, the farm dummy variable includes in addition to management contribution the effect of any factors that influence output but that are not explicitly represented in the production function specification. Massell (1967) followed similar steps by pooling product and farm data cross-sectionally.

It is obvious that the above approach uses covariance analysis in order to split the residual between farm effect and temporal effect and, therefore, is an indirect method of measuring management contribution. Moreover, it requires extensive data which proved to be often available in agriculture.

In the present analysis it is advanced that the employment of scientists and technologists in managerial activities may be used to assess the contribution of scientific management. In an inter-firm study the introduction of scientific management may be used to assess

---

(1) The form used is similar to:-

$$\ln O_{jt} = a_{oo} + a_{oj} + \bar{a}_{ot} + a_1 \ln L_{jt} + a_{2_1} \ln K_{jt} + u_{jt}$$

where O_{jt}, L_{jt} and K_{jt} is the output labour and capital of the firm j in year t, a_{oo} is a general constant term, a_{oj} is a farm efficiency coefficient, a_{ot} is a time coefficient and u_{jt} is the residual term.

management contribution in a scientifically oriented industry and thus it eliminates the management bias in the assessed production function. Scientific management is likely to be superior to the dummy variable as a measurement of management contribution.(1) Its use, in addition, is possible either in a cross-section or in a time series situation. The evaluation of the contribution of scientific management by the present study is limited by:-

1. the implication of the view advanced above that part of scientific management's effort, particularly that effort concerned with allocating resources towards improving future technology as well as ensuring the productiveness of these resources, may be taken as affecting future activities. Moreover, it is advanced that the rest of their effort is spent mainly in managing scientific effort on-the-shop-floor as well as co-ordinating this effort with research and development effort, and thus may be regarded as contributing to current productive activities. The two views may be taken to suggest that it is likely that the scientific management contribution may be described by a distributed lag. However, the available data does not allow experimentation in that direction with the view of arriving at an appropriate specification of scientific management effort.

2. the available data on scientific management is limited by the fact that it includes as well other activities such as sales, after sales services, etc. A further limitation is caused by the exclusion of all qualified social scientists from the Triennial Surveys who are well versed in management techniques (10 and (2) together amount to suggesting

---

(1) Since Scientific management is part of management its use here is treated as a proxy of management effort, yet it is more direct compared with other measures.

the lower quality of the available data for the purpose of evaluating the managerial contribution.

The application of the following form is suggestive

$$O = f(L_T, K_A, C, M, A) \qquad (1.10)$$

where O, L_T, K_A, C and M refer to net output, total labour, all fixed assets, the degree of capacity utilization, and the employed scientists and technologists in management; A is the technical efficiency term.

Equation (1.10) thus corrects for the degree of capacity utilization as well as scientific management. The assessment of the Cobb-Douglas gross output function of (1.10) provided by (11.4.20), indicates that all the coefficients are statistically significant at least at 20% level. Moreover, it shows that the amount explained of the residual, accordingly exceeds 31% of its counterpart (6.1.6). Further, if the vintage of capital is corrected for in addition (11.4.21) the amount explained of the residual of the traditionally specified production function exceeds 51%.

Some suggestions may now be made on the basis of these findings. These are:-

1. that ignoring scientific management (as well as other functions of scientific effort) in the specification of the aggregate production function seems likely to introduce bias in the assessed technical efficiency as well as in the assessed parameters of the production function and, in particular, the output elasticity with respect to capital. An overstatement of the capital coefficient, in agreement with the findings of Section D above, is shown to result from disregarding scientific input.

2. that scientific management is likely to be influential factor in explaining technical efficiency.

3. that scientific management as an input is likely to correct for management effort and thus tends to reduce managerial bias.

However it is important to note that:-

(a) The extremely high correlation between the number of scientists and technologists employed in managerial activities, research and development and the production department seems to be the main reason for the multi-collinearity which frustrated the attempt to assess simultaneously the relative contribution of each scientific function.

(b) The correlation coefficient between scientific management and the net stock of all fixed assets is relatively high (see table (11.1). It becomes greater with the net stock of plant and machinery and greater still with either modern capital or modern plant and machinery. In effect the attempt to improve the specification of the aggregate production function via allowing simultaneously for:-

(i) scientific management

(ii) the vintage of capital, and

(iii) the degree of capacity utilization.

resulted in a marked increase in the amount explained of the residual as indicated above. The price, however, is a deterioration in the significance of the coefficient of scientific management. Yet it remained greater than its standard error (i.e. significant at the 30% level).

G'. On-the-Shop-Floor Scientific Contribution:

It was advanced earlier that the scientific effort on-the-shop-floor is concerned with current productive activities. In other words the on-the-shop-floor scientists and technologists may be regarded as the main scientific contributors to the production of the same time period.(1)

The further implications of this view are:-

(i) A distinction is necessary between scientific effort on-the-shop-floor viz-a-viz other scientific functions, and

(ii) the loss in accuracy in specifying the aggregate production function caused by ignoring the input of on-the-shop-floor scientists and technologists is likely to impart a serious bias to the assessed technical efficiency as well as to the parameters of that function.

One of the direct means of investigating empirically the appropriateness of this view is to compare the contribution of science and technology on-the-shop-floor with the contribution of research and development and scientific management as derived simultaneously from the same aggregate production function. The main difficulty, it is to be recalled, lies in an unavoidable multicollinearity.

Rather less direct evidence for the view that scientific effort on-the-shop-floor is most relevant to current productive activities may be obtained by comparing the output elasticity with respect to the input of scientific effort on-the-shop-floor with the elasticity of other current scientific efforts. In order to free such a comparison from the harmful

---

(1) It is to be noted that the above comparison is drawn between the contribution of on-the-shop-floor and other scientific inputs of the same time period. It is highly likely that the contribution of, say an accurately specified distributed lag of research and development is greater than the contribution of a given year's research and development to the production of the same year.

effect of multicollinearity the input of capital is removed from the estimated production functions. The net output Cobb-Douglas function (11.5.3), (11.5.4) and (11.5.5) indicate that the contribution of the on-the-shop-floor scientific effort is on the average one and half times the elasticity with respect of current research and development personnel and the elasticity of scientific management. Moreover, equation (11.5.5) provides the highest explanatory power amongst the three estimates.

These findings amount to suggesting that the above view is probably appropriate for the sector of manufacturing industries. Moreover, the marked difference between the on-the-shop floor coefficient and the other two coefficients may be taken to suggest that the specification of scientific effort is likely to improve by observing a distinction between the three main scientific functions. This line is further supported through comparing the contribution of all scientists and technologists, (i.e. ignoring the suggested distinction amongst scientific functions), with the contribution of on-the-shop-floor personnel alone (estimates (11.5.8) and (11.5.5). The estimates indicate that the contribution of scientific effort on-the-shop-floor to current production is on the average larger than the average contribution of all scientific manpower. Also the introduction of the former's input allowed greater explanation of the productive activity vis-à-vis the latter.

These findings seem to suggest that it is likely that using the total number of scientists and technologists irrespective of the activities they are engaged in involves a mis-specification of scientific input.

H. Concluding Remarks:

In this concluding section it is not intended to consider the main findings in detail since this is done by the previous sections of this chapter. A consideration of various aspects of applying the suggested model in general terms is presented.

Data represented by and large the main limitation of this study. By estimating unobtainable information the results in some cases inherited some source of weakness, and on the whole the interpretations and the suggested conclusions based on the estimated data must be treated with caution and at best have to be regarded as suggestive. The consistency of the findings of the estimates based on the estimated data with the estimates based on the published data is a source of satisfaction. Also on the negative side of this study, multicollinearity (caused by the high correlation between some of the explanatory variables), frustrated the attempt to obtain a picture of the result of the effort aimed at avoiding the main sources of bias, sharper than the obtained one. However, time allowing, it should not be too difficult to find out a suitable deflator in order to reduce the causes of singularity of the explanatory variables matrix in some functions. Especially those which try to introduce the inputs of various types of scientific activity simultaneously.

On the positive side, the estimates obtained were on the whole statistically significant and suggestive. Although the traditional rule of 5% level of significance, in agreement with Professor Shcerer's view (1965), has to be relaxed especially in the case of studying the contribution of scientific effort.

The estimates arrived at in this study seem to suggest that the main views are not contradicted empirically. In other words the views summed up below may be regarded consistent in practice as they seem to be in theory. These are:-

Firstly: the mis-specification of the input factors of labour and capital brought about by ignoring the distinction between various qualities and structures as well as the less accurate specification of the production function which is involved by ignoring a correction for the degree of capacity utilization and an explicit introduction of scientific effort is likely to impart a bias in the estimated technical efficiency as well as the estimated parameters of the aggregate production function.

The findings are consistent in indicating that the amount explained of the residual as a result of avoiding each source of bias is appreciable. Moreover, a larger and larger improvement in the estimation of the production function is achieved by avoiding more and more of the sources of bias simultaneously.

The findings of applying the suggested improvements to the specification of the aggregate production function seem to be suggestive from policy points of view. They also indicate that the fears expressed by Chapter V of formulating present policy of future performances upon unsatisfactory or ad-hoc estimates seems to be largely supported and must be avoided as far as possible.

Secondly: an overstatement of the capital contribution seems to be the result of ignoring the introduction of scientific effort as an explicit factor of production. This is suggested by the estimates of sections D - F. This finding seems to be in agreement with the view that scientists and technologists are the innovators of newly produced capital that embodies the latest know-how as well as them being likely to be an influential element in increasing the efficiency of operating modern equipment in industry. The further implication of this finding is that capital variable is likely to represent part of the contribution of scientific effort in the production function which disregards this effort as an input factor.

Thirdly: the findings as a whole seem to be consistent with the general model which is suggested as an alternative to the growth models which are restricted by assuming that technological change is mainly:-

(a) embodied in newly produced capital equipment

(b) disembodied or organisational, and/or

(c) attributable to human experience.

This model adopts the view that part, but only part, of technical efficiency (or technological progress) is incorporated in newly produced capital. However, it advances further, that an appreciable part of the third factor may be attributed to scientific effort as an input factor influencing current and future productive activities. The further implication of the finding of an overstatement of capital coefficients including modern vintage of capital from the functions which exclude scientific effort seems to suggest that the percentage of productivity growth attributed to capital deepening effect (i.e. K/L ratio) by previous studies (e.g. Solow (1957) and Massel (1961)), are consequently overstated. This finding also implies that the assumption that technological progress is wholly embodied in newly produced capital seems to require further consideration.

SELECTED BIBLIOGRAPHY

BIBLIOGRAPHY

ABRAMOVITZ, M. : "Economic Growth", in Survey of Contemporary Economics, Vol. II, Edit. by B. F. Haley (Homewood, Illinois, Irwin for A.E.R., 1952.

" : "Resource and Output Trends in the U.S. since 1870". A.E.R., P & P., Vol.46, May, 1956.

" : "Economic Growth in the U.S." A.E.R., Vol.52, Sept. 1962, pp. 762-782.

AHMAD, S. : "On the Theory of Induced Invention", E.J., June, 1966.

AITKEN, A.C. : "On Least Squares and Linear Combinations", Proceedings of the Royal Society of Edinburgh, Vol.55, 1934, pp.42-48.

ALCHIAN, A.A. : "Costs and Outputs", in the Allocation of Economic Resources, Ed. M.ABRAMOVITZ, Stanford, Calif., Stanford Univ. Press, 1959.

" : "Reliability of Progress Curves in Airframe Production", Econometrica, Vol.31, No.4, Oct., 1963. pp. 679-693.

ALCHIAN, A.A., ARROW, K.J., & CAPRON, W.M.: "An Economic Analysis of the Market for Scientists and Engineers". The RAND Corpn. Santa Monica, California, June, 1958.

ALLEN, R.G.D. : "The Structure of Macroeconomic Models", E.J. Vol. 70. March, 1960.

AMES, E., & ROSENBERG, N.: "Changing Technological Leadership and Industrial Growth". E.J. Vol. 73, March, 1963.

ANDO, A. & SIMON, H.A.: "Aggregation of Variables in Dynamic Systems". Econometrica, Vol.29, April, 1961.

APPLETON, H. : "Private or Public Institutions in the U.S. which promote the Development of Inventions and speed their industrial application". O.E.C.D./D.A.S./R.S./63 181, 1963.

ARROW, K.J. : "Alternative Proof of the Substitution Theorem for Leontief Models in the general case", In Activity Analysis of Production and Allocation, ed.T.C. Koopmans, (Wiley, N.Y., 1951).

" : "Capital-Labour Substitution and Economic Efficiency". R.E. Stats. 1961.

" : "Economic Welfare and the Allocation of Resources for Inventions", The Rate and Direction of Inventive Activity, N.B.E.R., 1962.

ARROW, K.J. : "Comment on Case Studies", The Rate and Direction of Inventive Activity, N.B.E.R., 1962.

" : "The Economic Implications of Learning by Doing". R.E. Stud., June, 1962, pp. 155-173.

ARROW, K.J., ALCHIAN, A.A., & CAPRON, W.M.: "An Economic Analysis of the Market for Scientists and Engineers" The RAND Corpn. Santa Monica, California, June, 1958.

ASHER, H. : "Cost Quantity Relationships in the Airframe Industry". RAND. Report No. R - 291 (Santa Monica, California, July, 1956.

BALESTRA, P. & NERLOVE, M.: "Pooling Cross Section and Time Series Data in the Estimation of Dynamic Model. The Demand for Natural Gas". Econometrica, Vol.34, No. 3. July, 1966. pp. 585-612.

BARNA, T. : "Replacement cost of Fixed Assets in British Manufacturing Industry, 1955, J.R.S.S. Series A General, Vol. 120, 1957, p. 1 - 36.

BARNETT, H. : "Innovation". New York: McGraw, Hill Book Co., 1953.

BARZEL, Y. : "Productivity in the Electric Power Industry: 1829-1955", R.E. and Stats. Nov., 1963.

" : "The production function and technological change in the Steam Power Industry", J.P.E., April, 1964.

BAXTER, J. : "Scientists against Time". Boston: Little, Brown & Co., 1946.

BEAL, G. & BOHIEN, J.: "The Diffusion Process", Special Report No. 18. Agricultural Extension Service (Iowa State College, 1957.)

BECKER, G. : "Investment in Human Capital: A Theoretical Analysis", J.P.E., Vol.70, 1962.

" : "Human Capital", 1964.

BECKER, G., WHISLER, T.L.: "The Innovative Organisation: A selective view of current Theory and Research" J.B.U., Chic., Vol.40, Oct. 1967.

BELLO, F. : "The World's Greatest Industrial Laboratory", Fortune, Nov. 1948.

BLACK, J. : "The Technical Progress Function and the Production Function". Economica, Vol.29, No. 114. May, 1962. pp. 166-170.

BLACK, J. & EVANS, W.M.: "Innovation in Business Organisations: Some Factors associated with success or failure of Staff Proposals". J.B. U. Chic. Vol. 40, Oct., 1967.

BLANK, D.C., & STIGLER, G.: "The Demand and Supply of Scientific Personnel" N.B.E.R., N.Y. 1957.

BLAUG, M. : "A survey of the Theory of Process Innovations". Economica Feb., 1963, pp. 13-32.

" : "The Rate of Return on Investment in Education in G.B." The Manchester School, Sept. 1965. pp. 205-262.

BLAUG, B.M., PRESTON, M.H. & ZIDERMAN, A.: "The Utilization of Educated Manpower in Industry". L.S.E. Memographed Jan.1966.

BRECHLING, F. : "The Relationship between Output and Employment in British Manufacturing Industry". R.E. Stud., Vol.32, July, 1965, pp. 187-216.

BOHLEN, J. & BEAL, G.: "The Diffusion Process", Special Report No. 18. Agricultural Extension Service (Iowa State College, 1957).

BRANDEBURG, R. & MANSFIELD, E.: "The Allocation Characteristics and Outcome of firms Research and Development Portfolio". J. Bus. Univ. Chicago, Oct., 1966 p.1-14.

BROWN, M. & POPKIN, J.: "A measure of Technological Change and Returns to Scale". R.E. & Stats. Nov. 1962, pp. 269-274.

BROWN, M. : See footenote (1) , p. 48 e obove.

BROWN, W. : "Innovation in the Machine Tool Industry", Q.J.E., 1957.

BROZEN, Y. : "Invention, Initiation and Emulation"., A.E.R. May, 1951.

" : "Technological Change, Ideology & Productivity". Political Science Quarterly, Dec. 1955.

BUSH, V. : "Science: The Endless Frontier", Washin.D.C.: Govt. Printing Office, 1945.

BUSH, G.P., & HATTERY, L.H. (Eds): "Scientific Research - Its Administration and Organization". Washington, D.C.: American Univ. Press 1950.

BUTLER, W.F. : "Rates of Growth and their Limitations" J.F.E., 1964. pp. 1041 - 1050.

CAMPLE, McCONNELL & PETERSON: "Research and Development: Some Evidence for Small Firms" Southern E.J. 1964/65, pp. 356-364.

CARTER, C.F. & WILLIAMS, B.R.: "Industry and Technical Progress", (London Oxford Univ. Press, 1957).

" " "Investment in Innovation", London: Oxford Univ. Press 1958.

" " "Science in Industry" (London: Oxford Univ. Press 1959)

" " "Government Scientific Policy and the Growth of the British Economy" The Manch.Sc., Sept., 1964.

CATTELL, J. : "The Influence of the Intensity of Stimulus on the Length of the Reaction Time"; Reprinted in Dennis Readings in the History of Psychology (N.Y. Appleton, Century, Crofts, 1948.)

CHENERY, H.B. : "Process and Production Functions from Engineering Data", Studies in Structure of American Economy, (ed) W.W. Leontief, 1953.

CHOW, G.C. : "Tests of Equality Between sets of Coefficients in two Linear Regressions", Econometrica, Vol.28, July, 1960, pp. 591-605.

CLUNIES-ROSS, C.W., FREUND, R.J. & VAIL, R.W.: "Residual Analysis", J.A.S.A., March, 1961. Vol. 56, p. 98.

COLE, C.C. : "Encouraging Scientific Talent" N.Y. 1956.

COLEMAN, J., KATZ, E. & MENZEL, H.: "The Diffusion of an Innovation Among Physicians". Socieometry, Dec. 1957.

COMANOR, W.S. : "Research and Competitive Product differentiations in the Pharmaceutical Industry in the U.S." Economica, Nov. 1964. pp. 372-384.

" : "Research and Technical change in the Pharmaceutical Industry" R.E. and stats. May, 1965, pp. 182-190.

COMMITTEE ON PRICE DETERMINATION: Cost Behaviour and Price Policy, N.B.E.R., 1943.

CONWAY, R. W. & SCHULTZ, A. Jnr.: The Manufacturing Progress Function" Journal of Ind. Eng. Vol.10, Jan - Feb. 1959, pp. 39-54.

CREAMER, D.B. : "Capital expansion and capacity in Post-war Manufacturing" N.Y. National Industrial Conference Board, 1961.

DACY, D. : "A Price and Productivity Index For a Nonhomogeneous Product", J.A.S.A. Vol. 59, June, 1964. pp.469-480.

DEAN, G. : "The Lack of Fixed Capital in the United Kingdom, 1961" J.R.S.S., Series A (General), Vol.127, part 3, 1964.

DENISON, E.F. : "Theoretical Aspects of Quality change, Capital Consumption and Net Capital Formation" in NBER Stds, in Income and Wealth. Vol.19,p p.215-261. 1953.

" : "Measurement of Labour Input: Some Questions of Definition and the Adequacy of Data", in conference on Research in Income and Wealth, Output, Input, and Productivity Measurement, Studies in Income and Wealth, Vol. 25, Princeton, Princeton Univ. Press, 1961, pp. 347-372.

" : "The Sources of Economic Growth in the U.S. with the Alternatives before us" Princeton, Princeton Univ. Press, 1964.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH: "Research and Development of Shipbuilding and Marine Engineering". 1960.

DHRYMES, P.J. & KURZ, M.: "Technology and Scale in Electricity generation", Economica, July, 1964. pp. 287-315.

DHRYMES, P.J. : "Some Extensions and Tests for the Constant Elasticity of Substitution Class of Production Function," R.E. Stats. 1965.

DIAMOND, P.A. : "Technological Change and the Measurement of Capital and Output" R.E. Stud. Vol.32, Oct., 1965, pp.289-298.

DOMAR, E.D. : "Capital Expansion, Rate of Growth and Employment", Econometrica, Vol.14, April, 1946.

" : "Essays in the Theory of Growth", (London: Oxford Univ. Press, 1957).

" : "Depreciation, Replacement, and Growth and Fluctuations," E.J. Vol.67, 1957, pp. 655-658.

" : "On the Measurement of Technological Change" E.J. Dec. 1961.

" : "Total Productivity and the Quality of Capital", J.P.E., Vol.71, Dec.1963, pp. 586-588.

DOMAR, E.D. et al: "Economic Growth and Productivity in the U.S. Canada, U.K., Germany and Japan in post War Period", R.E. & Stats. Feb., 1964.

DUNLOP, J.T.: "The Movement of Real and Money Wages", E.J., Vol., 48, Sept., 1938.

DURBIN, J. : "A Note on Regression Where there is Extraneous Information About One of the Coefficients", J.A.S.A. Vol.48, Dec.1953, pp.799-808.

EVAN, W.M. & BLACK, G.: "Innovation in Business Organizations: Some Factors Associated with Success or Failure of Staff Proposals" JBU Chic. Vol.40. Oct. 1967.

ECKAUS, R.S. : "The Factor proportions problem in Economic Development" A.E.R. Vol.45, Sept. 1955.

" : "Economic Criteria for Education and Training", The R. of E. & Stats. Vol. 46, May, 1964, pp. 181-190.

" : "Notes on Invention And Innovation in Less Developed Countries", A.E.R., Pop & Proc. Vol. 56, pp. 98-107.

ECKSTEIN, O, & WILSON, T.: "Short Run Productivity Behaviour in U.S. Manufacturing", R.E. and Stats., Feb., 1964, pp.41-54.

EISNER, R. : "A Distributed Lag Investment Function" Econometrica, Vol. 28, Jan. 1960 pp. 1 - 29.

ELTIS, W. : "Investment, T.P., and Economic Growth" O.E.P., 1963.

ENOS, J. : "The History of Cracking in the Petroleum Refining Industry", (Ph.D. Thesis, M.I.T. 1958)

" : "Invention and Innovation in the Petroleum Industry", The Rate and Direction of Inventive Activity. N.B.E.R.), 1962.

EVANS, W.D. : "The Production Economics of Growth", American Economic Review, May, 1956.

EWELL, R.H. : "Role of Research in Economic Growth". Ceml. and Eng. News, June, 1955.

FABIAN, Y. : "Measurement of Output of Research and Development". O.E.C.D./D.A.S./P.D./63, 48, 1963.

FABRICANT, S. : "Basic Facts on Productivity Change", Occasional Paper 63, N.B.E.R., N.Y., 1959.

" : "Economic Progress and Economic Change", 34th Annual Report of the N.B.E.R.

FEDERATION OF BRITISH INDUSTRY: Research and Development in British Industry". 1950 - 51.

" : "Industrial Research in Manufacturing Industry", 1961.

FELDSTEIN, M.S. : "Specification of the Labour Input in the Aggregate Production Function". R.E. Stud. Vol. 34, 1967, pp. 375-386.

" : "Alternative Methods of Estimating a C.E.S.P.F. for Britain". Economica, Vol. 34, 1967, pp. 384-394.

FELLNER, W. : "The Influence of Market structure upon Technological Progress". Q.J.E., Nov. 1951.

" : "I. Two Propositions in the Theory of Induced Innovations", J.E., June, 1961.

" : II. "Appraisal of Labour-saving and Capital Saving Character of Innovations", in the Theory of Capital, Proceedings of International Economic Assoc. Conference, ed. LUTZ & HAGUE (London: MacMillan, 1961).

" : "Does the Market Direct the Relative Factor-saving Effects of Technological Change". in the Universities, N.B.E.R. "The Rate and Directions of Inventive Activity (Princeton: Princeton Univ. Press, 1962).

FERGUSON, C.E. : "Cross-section Production Function and the Elasticity of Substitution in American Manufacturing Industry". The R.E. & Stats. pp. 305 - 313.

FISHER, F.M. & KAYSEN, C.: "The Demand for Electricity in the U.S.A., Study in Econometrics", Contributions to Economic Analysis (Amsterdam: North Holland Publishing Co., 1962).

FISHER, F.M. : "Embodied Technological Change and the Existence of an Aggregate Capital Stock" R.E. Stud. Vol. 32, Oct., 1965, pp. 253-288.

FOSS, M. : "The Utilization of Capital Equipment", Survey of Current Business, Vol.43, June, 1963, pp. 8 - 16.

FREEMAN, C. : "Research and Development: A comparison Between British and American Industry". National Institute Economic Review, May, 1962.

" : "The Plastic Industry: A comparative study of Research, and Innovation", National Institute Economic Review, Nov. 1963.

" : "An Experimental International Comparison of Research Expenditure and Manpower in 1962". O.E.C.D/S.R. (65.31), 1965.

FREUND, R.J., VAIL, R.W., & CLUNIES-ROSS, C.W.: "Residual Analysis" J.A.S.A., March, 1961 Vol. 56, pp. 98ff.

FRIEDMAN, M. : "Testing the significance among a group of Regression Equations," Econometrica, Vol. V (1937), pp. 194-195.

GILFILLAN, S.C. : "Inventiveness by Nation and State", J. of the Patent Office Society, June, 1930.

" : "Inventing the shop", Chicago, Follett Publishing Co. 1935.

GILFILLAN, S.C. : "Prediction of Technological Change". R.E. & Stats. Nov. 1952.

GOLDBERGER, A. & JOCHEMS, D.B.: "Note on Stepwise Least Squares", J.A.S.A., Vol. 56, March, 1961, pp. 105-110.

GOLDBERGER, A. : "Best Linear Unbiased Prediction in the Generalised Linear Regression Model" J.A.S.A., Vol. 57, June, 1962, pp. 369-375.

GORDON, M. : "The Payoff Period and the Rate of Profit" Journal of Business, Oct. 1955.

GRILICHES, Z. : "Hybrid Corn: An Exploration in the Economics of Technological Change", Econometrica, Oct. 1957.

" : "Research Costs and social Returns: Hybrid Corn and Related Innovations", J.P.E. Oct. 1958.

" : "The Sources of Measured Productivity Growth: U.S. Agriculture 1940 - 1960, J.P.E. Aug. 1963. Vol. 71, pp. 331-346.

" : I. "Research Expenditures, Education and the Aggregate Agricultural Production Function". A.E.R., Vol. 54, Dec. 1964. pp. 61-74.

" : II. "Notes on the Measurement of Price and Quality Changes", in Conference on Research in Income and Wealth, Models of Income Determination, Princeton, Princeton Univ. Press, 1964, pp. 381-404.

GRILCHES, Z. & JORGENSON, D.: "Sources of Measured Productivity Change: Capital Input, A.E.R., Vol. 56, May, 1966 pp. 50-61.

" " : "The explanation of Productivity Change", R.E. Stud. Vol. 34, 1967, pp. 249-283.

GRILICHES, Z. : "Production Function in Manufacturing: Some Preliminary Results", in Conference on Research in Income and Wealth; Production Relations (N.Y. Columbia Univ. Press. 1967. Vol. 31. pp.275-321.

GUPTA & NICHOLSON: "Output and Productivity Changes in British Manufacturing Industry. 1948 - 1954, A Study from Census of Production Data", JRSS 1960.

GUSTAFSON, W.E. : "Research and Development New Products and Productivity Change". A.E.R., May, 1962.

HAAVELMO, T. : "A Study in the Theory of Investment", Chicago. The Univ. of Chicago Press, 1960.

HAHN, F. & MATTHEWS, R.: "The Theory of Economic Growth: A Survey". E.J. Dec., 1964.

HALTER, CARTER, & HOCKING: "A Note on the Transcendental Production Function". J.F.E., 1957. pp. 966.

HAMBERG, D. : "Size of Firm, Oligopoly, and Research: The Evidence". Can. J.E. & P.S. Vol. 30, Feb. 1964.

" : "Invention in the Industrial Research Laboratory". J.P.E., Vol. 71, April, 1963. pp. 95-115.

" : "Essays on the Economics of Research and Development". Random House, Inc., N.Y. 1966.

HANSEN, W.L. : "The shortage of Engineers". R.E. & Stats. Aug. 1961.

HARROD, R.F. : "An Essay in Dynamic Theory" E.J. Vol. 49, Mar. 1939.

" : "Towards Dynamic Economics". London, Macmillan, 1948.

" : "Domar and Dynamic Economics". E.J. Vol. 69, Sept. 1959.

HART, P.E., MILLS, G. & WHITAKER, J. K. eds: "Econometric Analysis for National Economic Planning". Calston Papers No. 16. London, Butterworth, 1964.

HAYEK, F. A. : "The Use of Knowledge in Society", A.E.R. Sept. 1955.

HAZLEWOOD, A. & VANDOME, P.: "A Postmortem on Econometric Forecasts for 1959", OIS, Vol. 23, Feb. 1961, pp. 67-81.

HAZLEWOOD, A., VANDOME, P., & KLEIN, L.R.: "A re-estimation of the Econometric Model of the U.K. & Forecasts for 1961", OIS, Vol. 23, Reb. 1961, pp. 49-66.

HEALY, K. : "Regularization of Capital Investment in Railroads" in Regularization of Business Investment," NBER, 1954.

HEINZE, STEIN & SHIRLEY: "Creativity and Individual". Clancee, Illinois: Free Press, 1960.

HERTZ, D.B. : "The Theory and Practice of Industrial Research". New York: McGraw-Hill Book Co., 1950.

HICKS, J. : "Theory of Wages" (London, 1932), Capt. 5.

* HILL, T.P., KNOWLES, K.G.: "The Variability of Engineering Earnings", OIS., Vol. 18, May, 1956, pp. 79-139.

HILL, T.P. : "An Analysis of the Distribution of Wages and Salaries in G.B." Econometrica Vol. 27, July, 1959, pp.355-381.

HIRSH, W.Z. : "Manufacturing Progress Functions". Review of E. & Stats. Vol. 34, May, 1952. pp. 143-155.

HIRSHLEIFER, J. : "The Firm's Cost Function: A Successful Reconstruction" Journal of Business, Vol. 35, (July, 1962) pp. 235-255.

* HILDEBRAND, G.H. & TA-CHUNG LIU: "Manufacturing Production Functions in the U.S., 1957" N.Y.State School of Industrial and Labour Relations, Cornell Univ., Ithaca, N.Y.1965.

HOCH, J. : "Simultaneous Equation Bias in the Context of the Cobb-Douglas Production Function". Econometrica, 1958.

" : "Estimation of Production Function Parameters Combining time-series and Cross-Section Data". Econometrica, 1962.

HOCH, J. & MUNDLAK, Y.: "Consequence of Alternative Specifications in Estimation of Cobb-Douglas Production Functions", Econometrica, Vol. 33, 1965, pp. 814 ff.

HODGE, M.H. : "Rate your Company's Research Productivity", Harvard Business Review, Nov. 1963.

HOLT, C., MODIGLIANI, F., MUTH, J. & SIMON, H.: "Planning Production Inventories and Work Forces". Englewood Cliffs. N.J., Prentice-Hall, Inc. 1960.

HOUTHAKKER, H.S. : "Education and Income"., R.E. & Stats. Vol. 41, Feb., 1959, pp. 24-28.

HUANG & ZELLNER, A.: "Further Properties of Efficient Estimators for seemingly unrelated Regression Equations". International E.R., Vol. 3, 1962, pp. 300 - 313.

HULTGREN, T. : "Changes in Labour Cost During Cycles". in the Production & Business, NBER, Occasional Paper 74. (N.Y.1960).

HUNT, S.J. : "Income Determinants for College Graduates and the Return to Educational Investment". Yale Economic Essays. 1965.

INSTITUTE OF CHEMICAL ENGINEERS: "Symposium on Productivity in Research". Held Dec. 1963. Published April, 1964.

INTRILIGATOR, M.D: "Embodied Technological Change and Productivity in the U.S. 1929 - 1958". R.E. Stats. Vol. 47, 1965.

JEROME, H. : "Mechanization in Industry". NBER, 1934.

JEWKES, J., SAWERS, D., & STILLERMAN, R: "The Sources of Invention". St. Martin's Press, 1958.

JOCHEMS, D.B., & GOLDBERGER, S.: "Note on Stepwise Least Squares". J.A.S.A. Series A Vol. 56, Mrch. 1961. pp. 105-110.

JOHANNSEN, L. : "Substitution versus Fixed Production Coefficients in the Theory of Economic Growth: A Synthesis". Econometrica, 1959.

" : "A Method of Separating the effects of Capital Accumulation & Shifts in Labour Productivity upon Growth in Labour Productivity", E.J. Vol. 71., Dec. 1961.

JOHNSTON, J. : "Statistical Cost Functions in Electricity Supply". OEP, N.S., Vol. 4., 1952, pp. 68 - 105.

" : "Cost-Output Variations in a Multiple Firm". M.Sch. Vol. 21, 1953. p. 140.

" : "Statistical Cost Functions". (N.Y. 1960)

" : "Econometric Methods", (McGraw-Hill Book Co. 1963).

JOHNSTON, R.E. : "Technical Progress and Innovation". OEP, Vol.18, July, 1966. pp. 158 - 176.

JORGENSON, D. : "Capital Theory and Investment Behaviour". AER. Pap. & Proc. May, 1963. Vol. 53.

" : "Anticipation & Investment" in the Brookings Quarterly Econometric Model of the U.S. economy, ed. J. Duesenberry, G. From, L. Klein, & E. Kuh, Chicago: Rand McNally & Co., 1965.

" : "The Embodiment Hypothesis", JPE, Feb. 1966. pp. 1 - 17.

JORGENSON, D. & GRILCHES, Z.: "Sources of Measured Productivity Change: Capital Input". AER., Vol. 56, May, 1966. pp. 50 - 61.

" " : "The explanation of Productivity Change". R.E. Stud. Vol. 34, 1967, pp. 249-283.

KALDOR, N. : "A Model of Economic Growth". E.J., Dec. 1957, pp. 591 - 624.

" : "Capital Accumulation & Economic Growth" in F.A. Lutz & D.C. Hague (ed) The Theory of Capital (St. Martin's Press) 1961, pp. 177-222.

KALDOR, N. & MIRRLEES, J.A.: "A New Model of Economic Growth". R.E. Studs. June, 1962. pp. 174-192.

KALISKI : "Extraneous Estimate & Goodness of Fit". Manch.Sch. Jan. 1960.

KAROL, D. : "Soviet Research and Development". 1959.

KATZ, E., COLEMAN, J. & MENZEL, H.: "The Diffusion of an Innovation Among Physicians. Sociometry, Dec. 1957.

KAYSEN, C. & FISHER, F.M.: "The Demand for Electricity in the U.S.A., Study in Econometrics". Contributions to Economic Analysis, (Amsterdam: North Holland Publishing Co., 1962).

KENDALL, M.G. : "The Advanced Theory of Statistic". (London: Charles Griffin & Co. Ltd., 1946) Vol.II. pp. 242 ff.

KENDRICK, J.W. : "Some Theoretical aspects of Capital Measurement" AER Vol. 51, May, 1961, pp. 102-111.

" : "Productivity Trends in the U.S." NBER, N.Y. 1961.

KENNEDY, C. : "Technical Progress & Investment", E.J. June, 1961.

" : "Induced Bias in Innovation and the Theory of Distribution" E.J. Vol. 74, Sept., 1964. pp. 541-547.

KLEIN, B. & MECKLING, W.: "An Application of Operations Research to Development Decisions"., Operations Research, Vol.6, 1958.

KLEIN, B. : "A Radical Proposal for Research and Development." Fortune, Vol. 57, May, 1959.

KLEIN, L.R. : I "Macroeconomics and the Theory of Rational Behaviour" Econometrica Vol. 14, 1946, pp. 93-108.

" : II "Remarks on the theory of Aggregation", Econometrica, Vol.14, 1946, pp. 303-312.

" : "Studies in Investment Behaviour", Conference on Business Cycle. NBER 1951.

" : "A Textbook of Econometrics" (Row, Peterson, 1953).

" : "The Estimation of Distributed Lag", Econometrica, Vol. 26, 1958. pp. 553-565.

" : I. "Some Theoretical Issues in the Measurement of Capacity". Econometrica, Vol. 28, April, 1960. pp. 272-286.

" : II. "Single Equation versus Equation system methods of Estimation in Econometrics". Econometrica, Vol 28, Oct. 1960. pp. 866-871.

KLEIN, L.R. & NAKROMURA: "Singularity in the Equation systems of Econometrics, Some Aspects of the Problem of Multicollinearity". Int.E.R. Vol.3. Sept. 1962. pp. 274-299.

KLEIN, L.R. & PRESTON, R.: "Some New Results in the Measurement of Capacity Utilization". AER, Vol. 57, March, 1967.

KMENTA, J. : "Some Properties of Alternative Estimates of Cobb-Douglas Production Function". Econometrica Vol. 32, No. 1 - 2 (Jan - Apr. 1964) pp. 183 - 88.

KMENTA, J., ZELLNER, A. & DREZE, J.: "Specification and Estimation of Cobb-Douglas Production Function Models". Econometrica, Vol. 34, Oct. 1966.

KMENTA, J. : " Estimates of the Cobb-Douglass Production Function: a Reappraisal", Metroeconomica Vol.15,1963,pp.117-124

KNIGHT, P.T. & MADDALA, G.S.: "International Diffusion of Technical Change - A Case Study of the Oxygen Steel Making Process", E.J. Vol. 77. Sept. 1967, pp. 531-558.

KNIGHT, K.E. : "A Descriptive Model of Intra-Firm Innovation Process". J. of B. of Univ. of Chic., Vol. 40. Oct. 1967.

KOOPMANS, T.C. : "Three Essays on the state of Economic Science". N.Y.: MacGraw-Hill Book Co. Inc., 1957.

KOYCK, L.M. : "Distributed Lags and Investment Analysis". Amsterdam: North Holland Publishing Co. 1954.

KUH, E. & MEYER, J.R.: "How Extraneous are Extraneous Estimates". R.E. Stat. Vol.39. 1957 pp. 380-393.

KUH, E. : "The Validity of Cross-sectionally estimated Behaviour Equations in time series applications". Econometrica, Vol. 27 (Apr.1959) pp. 197-214.

" : "Cyclical and Secular Labour Productivity in U.S. Manufacturing". R.E. & Stats. Feb. 1965.

" : "Income Distribution and Employment over the Business Cycle" in The Brookings Quarterly Model of U.S. Chicago, 1965.

" : "Measurement of Potential Output"., AER. Vol.56, 1966.

KURAKOV, I. : "Science, Technology and Communism". Translated by S.V. Dedijer, 1965.

KURZ, M. : "Research and Development, Technological Change and Competitive Mechanism". Institute of Math.Stud. in Soc. Science. Stanford, 1962.

KURZ, M. & DHRYMES, P.J.: "Technology and Scale in Electricity generation". Economica, July, 1964. pp. 287-315.

KUZNETS, S. : "Capital in the American Economy", Princeton, Princeton Univ. Press, 1962.

LATIMER, R. and PAARLBERG, D.: "Geographic Distribution of Research Costs and Benefits," J.F.E. May, 1965.

LEVHARI, D. : "Extensions of Arrow's 'Learning by Doing' ", R.E. Stud. Vol. 33, Aprl. 1966 pp. 117-132.

LEVINE, H.S. : "A small Problem in the Analysis of Growth", Rev.E. Stats. Vol. 42, 1960, pp. 225-228.

LEVY, F.K. : "An Adaptive Production Function". A.E.R. P & P. Vol. 55, 1965, pp. 386-396.

LITTLE, A.D. : "Patterns and Problems of Technical Innovation in American Industry", Inc. in N.S.F./P.B./181573.

LIVIATAN, M. : "Consistent Estimate of Distributed Lags" International E. Review, Vol. 4, 1963, pp.44-52.

LONDON SCHOOL OF ECONOMICS: "Manpower Policy and Employment trends". London, 1966.

LUCAS, R.E. Jnr. : "Tests of a Capital-Theoretic Model of Technological Change". R.E. Stud. Vol. 34, 1967 pp. 175-189.

LUNDBERG, E. : "Produktivitet Och Rantabilitet" Stockholm: P.A. Norstedt and Söner, 1961

MACHLUP, F. : "The Production and Distribution of Knowledge in the U.S." 1962.

MACLAURIN, W.R. : "The sequence from Invention to Innovation and its relation to Economic Growth", A.E.R., Feb., 1953.

MADDALA, G.S. and KNIGHT, P.T.: "International Diffusion of Technical Change - A Case Study of the Oxygen Steel Making Process", E.J. Vol. 77, Sept. 1967, pp. 531-558.

MALINVAUD, E. : "Capital accumulation and Efficient Allocation of Resources". Econometrica Vol. 21. Apr. 1953.

MANSFIELD, E. : "Acceptance of Technical Change; The Speed of Response of Individual Firms", Multilithed, Carnegie Institute of Technology, 1957.

" : "Technical Change and The Rate of Imitation". Econometrica, Vol. 29, Oct. 1961, pp. 741-765.

" : "On the Rate of Diffusion of the Diesel Engine" Econometrica, 1962.

" : I "Entry, Gibrat's Law Innovation, and the Growth of Firms" A.E.R., Apr. 1963. Vol. 53, pp. 1023-1051.

" : II "The Speed of Response of Firms to New Techniques" Q.J.E., May, 1963. Vol. 67, pp. 290-311.

" : III "Intrafirm Rates of Diffusion of an Innovation" R.&E. Stats. Nov. 1963. pp. 348-358.

" : IV. "Size of Firm, Market structure and Innovation" J.P.E., Vol. 71, Dec. 1963, pp. 556-576.

" : I. "Research and Technological Change," Industrial Research, Feb. 1964.

" : II. "Industrial Research and Development Expenditures: Determinants, Prospects in Relation to size of Firm and Inventive Output,"J.P.E. Vol. 72, Aug. 1964, pp. 319-340.

" : "Rates of Return From Industrial Research &Development" A.E.R.P&P.Vol55,pp.310-322.

MANSFIELD, E. & BRANDEBURG, R.: "The Allocation Characteristics and Outcome of firms Research and Development Portfolio", J.Bus. Univ. Chicago, Oct. 1966, pp. 1 - 14.

MARKHAM, J. : "Inventive Activity: Government Conyrols and legal Environment", The Rate and Direction of Inventive Activity, N.B.E.R. 1962.

" : "Market structure, Business Conduct and Innovation", A.E.R., Vol. 55, May, 1965 pp.323 -332.

MARSHACK, J. & ANDREWS: "Random Simultaneous Equations and the Theory of Production", Econometrica, Vol. 12, 1944, pp. 143-205.

MARSHACK, T. : "Strategy and Organization in a System Development Project", p. 1901 the RAND Corporation, 1960.

MARSHALL, A.W. & MECKLINS, W.H.: "Predictability of the Costs, Time and Success of Development". The RAND Corporation, 1960.

MARSHALL : "Principles of Economics", MacMillan & Co. Ltd., for Royal Econ. Society, 1961.

MARX, K. : "Capital: A critical analysis of capitalist Production" Tran. from the third German ed. by S. Moore and E. Aveling, and ed. by F. Engels, London, 1909.

MASSELL, B.F. : "Capital Formation andTechnological Change in U.S. Manufacturing, R. & E. Stats. Vol. 42, 1960.

" : "A Disaggregated View of Technological Change", J.P.E., Dec. 1961.

" : "Determinants of Productivity Change in the United States Manufacturing". The RAND Corpn. Santa Monica California, 1962.

" : "Investment, Innovation and Growth", Econometrica, Apr. 1962.

" : "Estimation of Management Bias..."Em.,Vol.35,1967,pp495-508

MATTHEWS, & HAHN : "The Theory of Economic Growth: A Survey". E.J. Vol. 74, 1964.

McCONNELL, C.R. & PETERSON, W.C.: "Research and Development: Some Evidence for small Firms" Southern E.J. Apr. 1965. pp. 356-364.

McFADDEN, D.M. : "Further Results on Constant Elasticity of Substitution Production Function" R.E. Stud. Vol. 30, June, 1963.

MECKLING, W. & KLEIN, B.: "An Application of Operations Research to Development Decisions", Operation Research, Vol. 6, 1958.

MECKLINS, W.H. & MARSHALL, A.W.: "Predictability of the Costs, Time and Success of Development". The RAND Corporation, 1960.

MEES, C.E.K. & LEERMAKERS, J.A.: "The Organization of Industrial Scientific Research". New York: McGraw-Hill Book Co., 1956.

MENZEL, H., COLEMAN, J., & KATZ, E.: "The Diffusion of an Innovation Among Physicians", Sociometry, Dec. 1957.

MERTON, R.K. : "The Rate of Industrial Invention", Q.J.E., 1934-1935.

" : "Priorities in Science", American Sociological Review, Dec. 1957.

MEYER, J.R. & KUH, E.: "The Investment Decision", Cambridge, Harvard Univ. Press, 1957.

" " : "How Extraneous are Extraneous Estimates", R.E. Stat. Vol. 39, 1957, pp. 380-393.

MEYER, J.R. : "Transport Technologies for Developing Countries". A.E.R. Papers and Procg. 1966, pp. 83-90.

MILL, J.S. : "Principles of Political Economics: With some of their application to social Philosophy". People's ed. London, 1868.

MINASIAN, J.R. : "The Economics of Research and Development", The Rate and Direction of Inventive Activity, NBER, 1962.

MIRRLEES, J.A. & KALDOR, N.: "A New Model of Economic Growth" R.E. Studs. June, 1962, pp. 174-192.

MODIGLIANI, F., HOLT, C. MUTCH, J. & SIMON, H.: "Planning Production, Inventories and Work Forces" Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1960.

MUELLER, W.F. : "A Study of Product Discovery and Innovation Cost" Southern E.J. July, 1957.

MUELLER, A.J. & QUINN, J.B.: "On Whether to undertake next Phase of Research". Harvard Business Review. Jan. Feb. 1963.

MUNDLAK, V. : "Empirical Production Function Free of Management Bias", Journal of Form Economics, 1961.

" : "Estimation of Production and Behavioural Functions from a Combination of Cross-section and Time series Data", in Measurement in Economics, (Stanford Univ. Press, Stanford, Calif. 1963, pp. 138-166.

MUSKHIN, S. : "Economics of Higher Education". 1964.

MUTH, J., HOLT, C. MODIGLIANI, F. & SIMON, H.: "Planning Production Inventories and Work Forces". Englewood Cliffs, N.J. Prentice-Hall, Inc. 1960.

NATIONAL RESOURCES PLANNING BOARD: "Research: A National Resource, Part II: Industrial Research", Washington, D.C., Govt. Printing Office, 1940.

NATIONAL SCIENCE FOUNDATION: "Basic Research, A National Resource". Washington, D.C., Govt. Printing Office, 1957.

" : "Scientific and Technical Manpower Resources" Washington, D.C., Govt. Printing Office, (64-28) 1964.

NELSON, R. : "The Economics of Invention: A Survey of the Literature" Journal of Bus. April, 1959, Vol. 32, pp. 101 - 127.

" : "The simple Economics of Basic Scientific Research" JPE, Vol. 67, June, 1959.

" : "Uncertainty, Learning, and the Economics of Parallel Research and Development Efforts". R.E. and Stats. Vol. 43, 1961, pp. 351-364.

" : "Link between Science and Invention" in The Rate and Direction of Inventive Activity, NBER, 1962.

" : "Aggregate Production Function and Medium Range Growth Projections", AER Vol. 54, Sept. 1964. pp. 575-606.

" : "The Constant Elasticity of Substitution Production Function and Economic Growth Projections" R.E. Stat. Vol. 47. Aug. 1965, pp. 326-328.

NELSON, R. & PHELPS, E.S.: "Investment in Human Technological Diffusion, and Economic Growth, AER Paper & Procg. Vol. 55, 1965, pp. 69.

NERLOVE, M. : "Distributed Lags and Demand Analysis for Agricultural and Other Commodities". Wash.U.S., Govt.Printing Office, 1958.

NERLOVE, M. & BALESTRA, P.: "Pooling Cross section and Time Series Data in the Estimation of Dynamic Model; The demand for Natural Gas". Econometrica, Vol. 34, No. 3, July 1966, pp. 585-612.

NICHOLSON, R. & GUPTA, S.: "Output and Productivity Changes in British Manufacturing Industry" 1948-1954. A Study from Census of Production Data", JRSS 1960.

NICHOLSON, R. : "Capital Stock, Employment and Output in British Industry, 1948-1964". Yorkshire Bull.Econ. & Soc. Res. Vol. 18, Nov. 1966, pp. 1 - 21.

" : "The Measurement of Quality Changes", E.J. Vol. 77, Sept. 1967, pp. 512-530.

NIELD, R.R. : "Pricing and Employment in the Trade Cycle". London: Cambridge Univ. Press. 1963.

NIITAMO, O. : "The Development of Productivity in Finnish Industry, 1925-1952" Productivity Measurement Review, Vol. 15, Nov. 1958, pp. 30 - 41.

OECD. : "Science, Economic Growth and Government Policy", 1963.

" : "Resources of Scientific and Technical Personnel in O.E.C.D. Area". 1963.

" : "Employment Forecasting: International Seminar in Employment Forecasting Techniques, 1963.

" : "The Residual Factor and Economic Growth", 1964.

OI, W.V. : "The Neoclassical Foundation of Progress Functions", E.J. Vol. 77, Sept. 1967, pp. 579-594.

OKUN, A.M. : "Potential Gross National Product. Its Measurement and Significance" in Proceedings of the Business and Economic Stats. section of the American Statistical Assoc. 1962, pp. 98-104.

PAARLBERG, D. & LATIMER, R.: "Geographic Distribution of Research Costs and Benefits J.F.E., May, 1965.

PAGLIN, M. : "Surplus Agricultural Labour and Development: Facts and Theories, A.E.R., Sept., 1965.

PATINKIN, D. : "Price Flexibility and Full Employment", A.E.R., Vol. 38, Sept. 1948.

PAVITT, K. : "Research, Innovation and Economic Growth", Nature, Oct. 1963.

PECK, M. : "Inventions in the Postwar American Aluminium Industry", The Rate and Direction of Inventive Activity, N.B.E.R., 1962.

PERLES, B. : "Innovation in the Machine Tool Industry: A Comment". Q.J.E., 1963.

PETERSON, W.C. & McCONNELL, C.R.: "Research and Development: Some Evidence for small Firms". Southern E.J. Apr. 1965. pp. 356-364.

PHELPS, E. : "The New View of Investment: A Neoclassical Analysis", Q.J.E. Vol. 76, Nov. 1962.

PHELPS, E.S. & NELSON, R.: "Investment in Human,Technological Diffusion and economic Growth, A.E.R., Papers & Procg. Vol. 55, 1965. pp. 69ff.

PHELPS, E.S. & PHELPS, C.: "Factor-Price Frontier Estimation of a Vintage Production Model of the Postwar U.S. Non-Form Business Sector, R.E. & Stats. Vol. 48, Aug. 1966 pp. 251-265.

PHILLIPS, A. : "Concentration, Scale and Technological Change in selected Manufacturing Industries, 1899-1939." Journal of Industrial Economics. June, 1956.

PLANT, A. : "The Economic Theory Concerning Patents for Inventions", Economica, Feb. 1934.

POLANYI, M. : "Patent Reform", R.E. Studs., 1944.

POPKIN, J. & BROWN, M.: "A measure of Technological Change and Returns to Scale". R.E. & Stats. Nov. 1962, pp. 269-274.

PRESTON, L.E. & KEACHIE, E.C.: "Cost Function and Progress Functions", A.E.R., Vol. 54, March, 1964. pp. 100-107.

PRESTON, M.H., BLAUG, B.M. & ZIDERMAN, A.: "The Utilization of Educated Manpower in Industry" L.S.E. Memographed Jan, 1966.

PRESTON, R. & KLEIN, L.R.: "Some New Results in the Measurement of Capacity Utilization". A.E.R. Vol. 57, March, 1967.

PYATT, G. : "A Production Function Model", in Econometric Analysis for National Economic Planning", Ed., HART, MILLS & WHITHAKER,. Colston Papers No. 16, The Colston Research Society, 1964.

" : "Capital Output and Employment 1948-1960" 4th Vol. in: A programme for Growth (Chapman & Hall, Apr. 1964.)

QUINN, J.B. : "Yardsticks for Industrial Research". 1959.

QUINN, J.B. & MUELLER, A.J.: "On Whether to undertake next Phase of Research". Harvard Business Review, Jan., Feb., 1963.

RAPPING, L. : "Learning and World War II Production Function". R.E. & Stats. Vol. 7.

REDFERN, P. : "Net Investment in Fixed Assets in the U.K., 1938-1953". J.R.S.S., Series A (General), Vol. 118, Part 2, 1955.

REES, A. : "Pattern of Wages, Price and Productivity", ed. C. Myers. N.Y. American Assembly. Columbia.

" : "Wage Determination and Involuntary Unemployment". J.P.E., Vol. 4., 1951. pp. 143-153.

ROBENS, A.R. : "Engineering and Economic Progress", 1965.

ROBERTS, E.B. : "The Dynamics of Research and Development", N.Y. Harper and Row, 1964.

ROBINSON, J. : "The Accumulation of Capital", Irwin, 1956.

ROGERS, W.M. : "Diffusion of Innovations", 1962.

ROSENBERG, N. : "Capital Goods, Technology and Economic Growth", OEP, Nov. 1963.

ROSENBERG, N. & AMES, E.: "Changing Technological Leadership and Industrial Growth", E.J., Vol, 73, March, 1963.

ROSENBLATT, M. Ed.,: "Proceedings of the Symposium on Time Series Analysis held at Brown Univ. June 11th-14th 1962". London, Willy, 1963.

RUBENSTEIN, P. : "Problems of Financing and Managing new Research-Based enterprises in New England". Fed.Reserve Bank of Boston, 1958.

RUGGLES, R. : "The Nature of Price Flexibility and determinants of Relative Price Changes in the Economy". In Business concentration and price policy: A conference of the Univ. N.B.E.R. Princeton, N.J. Princeton Univ. Press, 1955.

SAHOTA, G.S. : "The Sources of Measured Productivity Growth: U.S. Fertilizer Mineral Industries" R.E. Stats. Vol. 48, 1966, pp. 36-60.

SALTER, W.E.G. : "Productivity and Technical Change" (London: Cambridge Univ. Press. 1960).

SAMUELSON, P.A. & SOLOW, R.M.: "A Complete Capital Model Involving Heterogeneous Capital Goods" Q.J.E. Vol.70, Nov.1956.

SARGAN, J.D. : "The Estimation of Economic Relationships Using Instrumental Variables" Econometrica (1958).

SAUNDERS, B.S. : "The Course of Invention", J. of the Patent Office Society, Oct. 1936.

SAWERS, D., JEWKES, J. & STILLERMAN, R.: "The Sources of Invention". St. Martin's Press, 1958.

SCHERER, F.M. : "I. "Size of Firm, Oligopoly, and Research: A Comment". Can.J.E. & P.S. May, 1965.

" : II. "Firm Size Market Structure, Opportunity and the Output of Patented Inventions". AER, Vol.55, Dec. 1965.

SCHMOOKLER, J. : "The Changing Efficiency of the American Economy", R. & E. Stats. Vol. 34, 1952.

" : "The Utility of Patent Stats." J. of the Patent Office Society, June, 1953.

" : "The Level of Inventive Activity". R.E. Stats. Vol.36. 1954, pp. 183-190.

SCHMOOKLER, J. & BROWNLEE, O.: "Determinants of Inventive Activity". AER, May, 1962.

SCHMOOKLER, J. : "Changes in Industry and in the state of Knowledge as determinant of Industrial Inventions", The Rate of Direction of Inventive Activity, NBER, 1962.

" : "Invention and Economic Growth", Harvard Univ. Press, 1965.

SCHRAMM, W. : "The Effects of Television on Children and Adolescents, UNESCO Publications, 1962.

" : "Mass Media and National Development", Stanford, Calif., Stanford Univ. Press, or Paris, UNESCO, 1964.

SCHUMPETER, J.A. : "The Theory of Economic Development", 1936.

SCHULTZ, A. Jr., & CONWAY, R.W.: The Manufacturing Progress Functions" Journal of Ind. Eng. Vol. 10, Jan-Feb. 1959. pp. 39-54.

SCHULTZ, T. : "The Economic Value of Education", 1964.

" : "Education and Economic Growth", Chicago, Univ. of Chicago Press, 1961.

" : "Capital Formation by Education" J.P.E. 1960.

" : "Reflection on Investment in Man" J.P.E. Vol. 70, Oct., 1962.

SCITOVSKY : "Economics of Scale and European integration" AER, March, 1956.

SCOTT, J.T. : "The Measurement of Technology", The JFE May, 1964, pp. 657-661.

SHAPERO, D., HOWELL, R. & TOMBAUGA, J.: "An exploratory study of the structure and Dynamics of the Research and Development Industry", June, 1964. (Stanford Research Institute).

SHELL, K. : "A Model of Inventive Activity and Capital Accumulation". Technical Report No. 2 (NSF: GS - 420) (Univ. of Chicago, Aug., 10, 1964.

" : "Towards a Theory of Inventive Activity and Capital Accumulation". AER Pap & Proc. Vol. 56, 1966, pp. 62-67.

SIEGAL, I. H. : "Concepts and Measurement of Production and Productivity", U.S. Bureau of Labour Stats., March, 1952.

SIEGAL, I.H. : "On the Design of Consistent Output and Input Indeces for Productivity Measurement", in conference On Research in Income and Wealth, Vol. 25, NBER, Princeton, Princeton Univ. Press. 1961, pp. 23-41.

SIEGAL, D.A. : "Scientific Discovery and the Rate of Innovation" The Rate and Direction of Inventive Activity, NBER, 1962.

SINHA, M.R. Ed. : "The Economics of Manpower Planning: A Symposium", Bombay, India: Asian Studies Press, 1955.

SIMON, H.A. & ANDO, A.: "Aggregation of Variables in Dynamic Systems". Em. Vol. 29, April, 1961.

SMITH, A. :See footenote (1) , P.12 obove.

SMITH, A.D. & REDAWAY, W.B.: "Progress in British Manufacturing Industries in the period 1948-1954" EJ. Vol. 70, March, 1960.

SOLO, R. : "The Capacity to assimilate An Advanced Technology". AER Papers & Proc. 1966. Vol. 56, pp. 91-97.

SOLOW, R.M. : "A Contribution to the Theory of Growth," QJE, Vol. 90, 1956, pp. 65-94.

SOLOW, R.M. & SAMUELSON, P.A.: "A Complete Capital Model Involving Heterogeneous Capital Goods". QJE, Vol. 70, Nov. 1956.

SOLOW, R.M. : "The Great Automation Question", The Public Interest. Vol. I, No.1.

" : "Heterogeneous Capital and Smooth Production Function: An Experimental Study" Econometrica, Vol. 31, 1963. pp. 523-545.

" : "Technological Change and the Aggregate Production Function"., R.E. Stat. Vol. 39, Aug. 1957.

" : "Investment and Technological Progress" in Mathematical Methods in the Social Sciences, ed. Arrow et al. (Stanford Univ. Press, 1960) pp. 89-104.

" : "Technological Progress, Capital Formation and Economic Growth". AER P & P Vol. 52, May, 1962.

" : "Subst. and Fixed Proportions in the Theory of Capital". R.E. Stud. Vol. 29, June, 1962.

" : "Capital Theory and the Rate of Return" Rand McNally & Co., 1964.

SOLOW, R.M., TOBIN, T., VON-WEIZACKER, C.C. & YAARI, M.E.: "Neoclassical Growth with Fixed Factor Proportions" R.E. Stud. Vol. 33, 1966, pp. 79-116.

STEIN, M.I. : "Creativity and the Scientist", in the Direction of Research Estabs. N.Y.: Philosophical Library, 1957.

STEIN, M.I., HEINZE, SHIRLEY, J.: "Creativity and Individual" Clarence, Illinois,: Free Press, 1960.

STILLERMAN, R., JEWKES, J. & SAWERS, D.: "The Sources of Invention", St. Martin's Press, 1958.

STURMEY, S.G. : "The Management of Research and Development"., J. Industrial Econ. Apr. 1966, Vol.14 (2) pp. 91-100.

SUTHERLAND, A. : "The Diffusion of an Invention in Cotton Spinning" J. Industrial Econs. Vol.V. March, 1959, pp.118-135.

SVENNILSON, I. : "Growth and Stagnation in the European Economy" Geneva, E.C.E., 1954.

" : "Capital Accumulation and National Wealth in an Expanding Economy". in 25 Economic Essays in Honour of Erik Lindahl, Stockholm: Ekonomisk Tidskrift, 1956.

SWALM, R. : "On Calculating the Rate of Return of an Investment", Journal of Industrial Engineering, March, 1958.

SALTZMAN, S. : "An Econometric Model of a Firm". R.E. Stats. Vol. 49. Aug. 1967.

TARSHIS, L. : "Changes in real and Money Wages". E.J. Vol. 49. March, 1939.

TAYLOR, J. : "A Surrogate for Regional Estimates of Capital Stock". Bull Oxford Inst. Econ. & Stat. Aug, 1967. Vol. 29. pp. 289-99.

TELSER, L.G. : "Iterative Estimation of a Set of Linear Equations", J.A.S.A. Vol. 59, Sept. 1964. pp. 845-862.

TERBORGH, G. : "Dynamic Equipment Policy" McGraw-Hill, 1949.

" : "Sixty years of Business Capital Formation", Washington, Machinery and allied Products Institute, 1960.

TERLECKYJ, N. : "Factors underlying Productivity". J.A.S.A., June, 1958.

" : "Research and Development: Its Growth and Composition" National Industrial Conference Board, 1963.

THANK, P. : "Production Process with Heterogeneous Capital". Econ.Record. Vol. 42, Sept. 1966, pp. 340 - 346.

THEIL, H. : "Linear Aggregation of Economic Relations", Amsterdam: North Holland Pub. Co. 1954.

THEIL, H. : "The Aggregation Implication of Identifiable Structural Macro-relations". Econometrica, Vol. 29, 1959, pp. 14-29.

" : "Economic Forecasts and Policy". (Amsterdam: North-Holland Publishing Co. 1958).

THUROW, B. L. & TAYLOR, L.E.: "The Interaction between the Actual and Potential Rates of Growth" R.E. Stats. Vol. 48, 1966.

TOBIN, J. : "Money Wage Rates and Employment" in the New Economics, Ed. Seymour Harris, London, 1948.

" : "A Statistical Demand Function for Food in the U.S.A." JRSS. Series A, 113 (Part II 1950), pp, 113-141.

TOBIN, J., SOLOW, R.M. & VON-WEIZACKER, C.C. & YAARI, M.E.: "Neoclassical Growth with Fixed Factor Proportions". R.E. Stud. Vol. 33, 1966. p. 79-116.

TYBOUT, R.A., ed.: "Economics of Research and Development". Publication of the Merasham Centre for Education in National Security, Columbus, Ohio State Univ. Press, 1965.

TOMBAUGA, J., SHAPERO, D., & HOWELL, R.: "Stanford Research Institute". "An Exploratory Study of the Structure and Dynamics of the Research and Development Industry". June, 1964.

U.N./E./ECE/454/add.l.: "Some Factors in Economic Growth in Europe During the 1950's". 1964.

U.N./E./3861 (E/C.5/52 Rev.): "Role of Patents Transfer of Technology to under-developed Nations".

URQUHART, M.C. : "Capital Accumulation, Technological Change and Economic Growth" Canadian Journal of Economy and Political Science, Vol. 25, Nov. 1959, pp. 411-430.

UZAWA, H. : "Production Function with Constant Elasticity of Substitution". R.E. Stud. Vol. 29, 1962.

" : "Optimum Technological Change in an Aggregate Model of Economic Growth" Int. E.R. Vol. 6, Jan, 1965. pp.18-31.

" : "Optimal Technological Change in an Aggregative Model of Economic Growth", RES, Vol. 32, 1965.

VAIL, R.W., FREUND, J.R., & CLUNIES-ROSS, C.W.: "Residual Analysis" J.A.S.A. March, 1961. Vol. 56, pp. 98ff.

VALAVANIS-VAIL : "An Econometric Model of Growth: U.S.A., 1869-1953". The AER. Vol. 45, May, 1955, pp. 208-221.

VAN DEUSEN, E.L. : "The Inventor in Eclipse", Fortune, Dec. 1954.

VANDOME, P., & HAZLEWOOD, A.: "A Postmortem on Econometric Forecasts for 1959". OIS, Vol. 23, Feb. 1961, pp. 67-81.

VANDOME, P., KLEIN, L.R. & HAZLEWOOD, A.: "A re-estimation of the Econometric Model of the U.K. and forecasts for 1961", OIS, Vol. 23. Feb. 1961, pp. 49-66.

VANDOME, P., KLEIN, L.R., BALL, R.J., & HAZLEWOOD, A.: "An Econometric Model of the U.K." Oxford, Basil Blackwell, 1961.

VANDOME, P., KLEIN, L.R., & HAZLEWOOD, A.: "Econometric Forecasting for the U.K." OIS, Vol. 25, Nov. 1963, pp. 239-281.

VANEK, J. : "The Labour Market, Technology and Stability in the Keynesion Model". Kyklos, Vol. 16, 1963, pp.111-122.

VERDOORN, P.J. : "Fattori Che Ragolano 10 Sviluppo Del Lavoro", L'Industria, 1 (1949)

VON-WEIZACKER, C.C., SOLOW, R.M., TOBIN, T., & YAARI, M.E.: "Neoclassical Growth with Fixed Factor Proportions". R.E. Stud. Vol.33, 1966, pp. 79-116.

WALTERS, A. : "A Survey of Cost and Production Function," Econometrica, Vol. 31, 1963. pp. 1-65.

" : "An Introduction to Econometrics". Macmillan, London, 1968.

WELCH, B.L. : "Some Problems in the Analysis of Regression Among K samples of Two Variables", Biometrika, Vol. 27, 1935. pp. 145-160.

WHISLER, T.L., & BECKER, S.W.: "The Innovative Organization: A selective view of Current Theory and Research". JBU Chic. Vol. 40. Oct., 1967.

WILLIAMS, C.F. : "Competition and Efficiency". Applied Economic Papers. (Osmonia Univ. India. Sept. 1962).

" : "Investment and Technology in Growth", Manchester Statistical Society, 8 Jan. 1964.

WILLIAMS, B.R. & CARTER, C.F.: "Industry and Technical Progress (London Oxford Univ. Press, 1957).

" " : "Investment in Innovation", London Oxford Press, 1958.

" " : "Science in Industry", (London Oxford Univ. Press, 1959.

" " : "Government Scientific Policy and the Growth of the British Economy". The March.Sc., Sept.'64.

WILSON, T. & ECKSTEIN, O.: "Short Run Productivity Behaviour in U.S. Manufacturing". R.E. & Stats., Feb., 1964. pp.41-54.

WILKINSON, B.W. : "Present Values of Lifetime Earnings for Different Occupations". JPE. Vol. 74, Dec., 1966, pp. 556-572.

WOLFE, J.N. : "The Representative Firm", E.J. Vol. 64, June, 1954, pp. 337-349.

" : "The Industry and the Representative Firm: A Rejoinder", E.J. Vol. 65, Dec. 1955, pp. 712-714.

" : "Transport Costs and Comparative Advantage". JPE, Vol.67 Aug. 1959, pp. 392-397.

" : "The Life and Death of the Firm", Econometrica, Vol. 28, 1960, p. 686.

WOLFE, J.N. & NEWMAN, P.K.: "An Essay on the theory of Value", Institute Paper No. 6. Inst. for Quantitative Research Econ. & Manag. Purdue, 1960.

WOLFE, J.N. : "Co-ordination Assumptions and Multiple Equilibria", QJE Vol. 75, May, 1961, pp. 262 - 277.

WOLFE, J.N. & NEWMAN, P.: "A Model for the Long-run theory of Value". R.E. Stud., Vol. 29, Oct., 1961, pp. 51-61.

WOLFE, J.N. & BRECHLING, F.: "Some Econometrics of Economic Growth". Memographed.

WOLFE, J.N. & FOLK: "The Ambiguity of the Substitution Term" EC.N.S. Vol.31, Aug. 1964, pp. 288-293.

WOLFE, J.N. & BRECHLING, F.: "The end of stop-go". LBR, Vol.75, Jan.1965, pp. 23-30.

WOLFE, J.N. : "Planning By Forecast", In Price Formation in Various Economics, D.C. Hague Ed., McGraw/Hill, N.Y. 1967.

WOLFE, J.N. & WRIGHT, W.D.: "The Central Borders: A Plan for Expansion", Vol. Two. H.M.S.O. 1968.

WOLFE, J.N. : "An Introduction" in J.N. Wolfe ed. of "Value, Capital and Growth Papers in honour of Sir John Hicks," Edinburgh Univ. Press. 1968, pp. vii-x.

WOODRUFF, W. : "Enquiry in to the origins of Invention and the Inter-Continental Diffusion Techniques of Production in the Rubber Industry". Economic Record. 1962.

*WRIGHT, T.P. : "Factors Affecting the Cost of Airframes", Journal of the Aeronautical Sciences, Vol. 3, Feb. 1936, pp.122-128.

*WORLEY, J.S. : " Industrial Research and The New Competition" JPE , Vol.69, 1961, pp.183-186.

WRIGHT, W.D. & WOLFE, J.N.: "The Central Borders: A Plan for Expansion", Vol. Two. H.M.S.O., 1968.

YAARI, M.E., SOLOW, R.M., TOBIN, T., & VON-WEIZACKER, C.C.: "Neoclassical Growth with Fixed Factor Proportions", R.E. Stud. Vol. 33, 1966. pp. 79-116.

ZELLNER, A. & HUANG: "Further Properties of efficient Estimators for seemingly unrelated Regression Equations". International E.R., Vol. 3, 1962, pp. 300-313.

ZELLNER, A. & THEIL, H.: "Three state Least Squares: Simultaneous Estimation of Simultaneous Equations". Econometrica, Vol. 30, 1962, pp. 54-78.

ZELLNER, A. : "An Efficient Method of Estimating seemingly unrelated Regression and Tests for Aggregation Bias". JASA, Vol. 57, 1962, pp. 348-368.

" : "Estimators of seemingly unrelated Regressions: Some exact Finite Sample Results", JASA, Vol.58, 1963, pp. 977-992.

ZIDERMAN, A., BLAUG, B.M., & PESTON, M.H.: "The Utilization of Educated Manpower in Industry". LSE Memographed, Jan. 1966.

SYNOPTIC APPENDICES

Synoptic Appendices

In Appendix I, the print-out of the main data used for British manufacturing industries is provided first. It is followed by a print-out of some important regressions.

In Appendix II the estimates of the restricted form of production function is provided. Also a comparison between the restricted and unrestricted forms is given.

Appendix III deals with specification errors and some of the tests used.

APPENDIX I

This appendix provides:-

Firstly , a print-out of most important variables used in the regressions for British manufacturing industries. It is to be noted that:-

a) The number of each variable in its absolute and log. form as used in the sample print-out of some important regressions ,(see below) , is provided by columns 2 & 3 of the summary table on page 284b.

b) The print-out of the variables is provided on pages 285-290 in columns. The abbreviation given at the top of each column is explained by column 4 of page 284b.

c) The number(s) of the table(s) and the number of the page(s) in which each variable is given in the text are provided by columns 5 & 6 of page 284b.

Secondly , a print-out of some important regressions is provided on pages 291-307 At the top of each regression the number of the estimated eqution in the text is given. It is to be noted that the number of each one of the dependent and independent variables as given in the print-out pages is explaind by columns 2 & 3 of page 284b , (see firstly).

APPENDIX I

DEL 1

15 VARIABLES
23 OBSERVATIONS
5 TRANSFORMED VARIABLES : LEVEL 1
20 TRANSFORMED VARIABLES : LEVEL 2

Key to the variables of U. K. Indusries.

Y TO RN.	Abslt.	Log.	Variable		In the text: Table No.	In the text: Page No
0	1	21	Gross output		(4.3)-(4.25)	78-100)
0	2	22	Net output		(4.26)	101-102
E	3	23	No. employed		(4.28)	104
M	4	24	Males		"	"
F	5	25	Females		"	"
A	6	26	Net stocks of fixed assets		(4.32)	112-113
AN	7	27	Modern " " "		(4.27)	103
F	8	28	Labour force		(4.28)	104
P	9	29	Net stocks of plant & machinery		(4.32)	112-113
K_{PN}	10	30	Modern " "		(4.27)	103
R_{62}	11	31	R & D scientists & technologists	1962	(4.2)	77
56	12	32	" " "	1956	(4.1)	75
E_{ST}	13	33	Total " "	1962	(4.2)	77
F	14	34	On-the-shop-floor "	1962	(4.2)	77
M	15	35	Managerial & others "	1962	"	"
	16	36	Intermediates		By substn.	
C	17	37	Degreeof capacity utilization		As a ratio	
K_O	18	38	Net stocks of other structures		(4.32)	112-113
K_{AR}	19	39	Older stocks of all assets		(4.27)	103
K_{A-PN}	20	40	Stocks of all assets exluding modern plant &machinery and machiny.		"	"

DATA PRINT-OUT

CONST.		GO		NO		L_E		L_M		L_F		K_A		K_{AN}	
1.000000$_{10}$	0	4.871400$_{10}$	4	1.166900$_{10}$	4	8.420000$_{10}$	2	4.757000$_{10}$	2	3.663000$_{10}$	2	9.330000$_{10}$	2	6.056000$_{10}$	2
1.000000$_{10}$	0	5.373000$_{10}$	3	6.260000$_{10}$	2	3.140000$_{10}$	1	2.600000$_{10}$	1	5.400000$_{10}$	0	2.578000$_{10}$	2	1.303000$_{10}$	2
1.000000$_{10}$	0	2.339700$_{10}$	4	8.968000$_{10}$	3	4.863000$_{10}$	2	3.475000$_{10}$	2	1.388000$_{10}$	2	1.266300$_{10}$	3	7.924000$_{10}$	2
1.000000$_{10}$	0	1.458800$_{10}$	4	6.404000$_{10}$	3	4.515000$_{10}$	2	4.057000$_{10}$	2	4.580000$_{10}$	1	1.061900$_{10}$	3	7.522000$_{10}$	2
1.000000$_{10}$	0	6.055000$_{10}$	3	1.714000$_{10}$	3	1.371000$_{10}$	2	1.102000$_{10}$	2	2.690000$_{10}$	1	1.768000$_{10}$	2	1.134000$_{10}$	2
1.000000$_{10}$	0	2.718400$_{10}$	4	1.260000$_{10}$	4	1.198200$_{10}$	3	9.853000$_{10}$	2	2.129000$_{10}$	2	7.904000$_{10}$	2	5.030000$_{10}$	2
1.000000$_{10}$	0	2.387000$_{10}$	3	1.595000$_{10}$	3	1.508000$_{10}$	2	9.510000$_{10}$	1	5.570000$_{10}$	1	7.740000$_{10}$	1	5.160000$_{10}$	1
1.000000$_{10}$	0	1.140900$_{10}$	4	5.954000$_{10}$	3	4.954000$_{10}$	2	3.300000$_{10}$	2	1.656000$_{10}$	2	2.946000$_{10}$	2	1.916000$_{10}$	2
1.000000$_{10}$	0	6.301000$_{10}$	3	3.736000$_{10}$	3	3.323000$_{10}$	2	1.884000$_{10}$	2	1.439000$_{10}$	2	1.706000$_{10}$	2	1.138000$_{10}$	2
1.000000$_{10}$	0	4.122000$_{10}$	3	2.116000$_{10}$	3	2.504000$_{10}$	2	2.377000$_{10}$	2	1.270000$_{10}$	1	1.381000$_{10}$	2	7.820000$_{10}$	1
1.000000$_{10}$	0	1.482000$_{10}$	4	5.917000$_{10}$	3	4.251000$_{10}$	2	3.677000$_{10}$	2	5.740000$_{10}$	1	5.544000$_{10}$	2	3.281000$_{10}$	2
1.000000$_{10}$	0	6.236000$_{10}$	3	3.233000$_{10}$	3	2.918000$_{10}$	2	2.487000$_{10}$	2	4.310000$_{10}$	1	1.943000$_{10}$	2	9.400000$_{10}$	1
1.000000$_{10}$	0	2.548000$_{10}$	3	1.132000$_{10}$	3	1.641000$_{10}$	2	1.461000$_{10}$	2	1.800000$_{10}$	1	8.720000$_{10}$	1	3.790000$_{10}$	1
1.000000$_{10}$	0	1.453700$_{10}$	4	5.608000$_{10}$	3	5.511000$_{10}$	2	3.610000$_{10}$	2	1.901000$_{10}$	2	3.625000$_{10}$	2	2.083000$_{10}$	2
1.000000$_{10}$	0	5.967000$_{10}$	3	2.190000$_{10}$	3	3.109000$_{10}$	2	1.439000$_{10}$	2	1.670000$_{10}$	2	2.871000$_{10}$	2	1.099000$_{10}$	2
1.000000$_{10}$	0	5.338000$_{10}$	3	1.735000$_{10}$	3	1.892000$_{10}$	2	8.880000$_{10}$	1	1.004000$_{10}$	2	1.380000$_{10}$	2	5.600000$_{10}$	1
1.000000$_{10}$	0	8.398000$_{10}$	3	3.752000$_{10}$	3	3.411000$_{10}$	2	1.539000$_{10}$	2	1.872000$_{10}$	2	4.332000$_{10}$	2	1.816000$_{10}$	2
1.000000$_{10}$	0	1.765000$_{10}$	3	6.040000$_{10}$	2	6.280000$_{10}$	1	3.640000$_{10}$	1	2.640000$_{10}$	1	2.840000$_{10}$	1	1.310000$_{10}$	1
1.000000$_{10}$	0	8.856000$_{10}$	3	4.095000$_{10}$	3	5.859000$_{10}$	2	1.586000$_{10}$	2	4.273000$_{10}$	2	1.371000$_{10}$	2	6.810000$_{10}$	1
1.000000$_{10}$	0	7.449000$_{10}$	3	4.117000$_{10}$	3	3.512000$_{10}$	2	2.691000$_{10}$	2	8.210000$_{10}$	1	3.541000$_{10}$	2	2.116000$_{10}$	2
1.000000$_{10}$	0	6.066000$_{10}$	3	2.461000$_{10}$	3	2.882000$_{10}$	2	2.297000$_{10}$	2	5.850000$_{10}$	1	1.386000$_{10}$	2	7.160000$_{10}$	1
1.000000$_{10}$	0	1.534900$_{10}$	4	7.870000$_{10}$	3	6.273000$_{10}$	2	4.079000$_{10}$	2	2.194000$_{10}$	2	5.832000$_{10}$	2	3.670000$_{10}$	2
1.000000$_{10}$	0	7.081000$_{10}$	3	3.250000$_{10}$	3	3.068000$_{10}$	2	1.858000$_{10}$	2	1.210000$_{10}$	2	2.597000$_{10}$	2	1.481000$_{10}$	2

L_F	K_P	K_{PN}	R_{62}	R_{56}	T_{ST}	F	M
8.570000$_{10}$ 2	5.126000$_{10}$ 2	3.201000$_{10}$ 2	9.810000$_{10}$ 2	4.520000$_{10}$ 2	2.775000$_{10}$ 3	1.832000$_{10}$ 3	4.120000$_{10}$ 2
3.200000$_{10}$ 1	1.960000$_{10}$ 2	1.041000$_{10}$ 2	7.630000$_{10}$ 2	4.620000$_{10}$ 2	1.919000$_{10}$ 3	9.400000$_{10}$ 2	2.160000$_{10}$ 2
4.920000$_{10}$ 2	9.093000$_{10}$ 2	5.626000$_{10}$ 2	6.111000$_{10}$ 3	3.960000$_{10}$ 3	1.572500$_{10}$ 4	6.686000$_{10}$ 3	2.487000$_{10}$ 3
4.660000$_{10}$ 2	8.184000$_{10}$ 2	6.101000$_{10}$ 2	9.380000$_{10}$ 2	4.840000$_{10}$ 2	3.771000$_{10}$ 3	2.135000$_{10}$ 3	2.980000$_{10}$ 2
1.390000$_{10}$ 2	1.130000$_{10}$ 2	7.860000$_{10}$ 1	6.250000$_{10}$ 2	4.220000$_{10}$ 2	1.877000$_{10}$ 3	8.970000$_{10}$ 2	3.870000$_{10}$ 2
1.211000$_{10}$ 3	4.932000$_{10}$ 2	3.131000$_{10}$ 2	2.736000$_{10}$ 3	1.871000$_{10}$ 3	1.243400$_{10}$ 4	6.493000$_{10}$ 3	3.205000$_{10}$ 3
1.520000$_{10}$ 2	4.350000$_{10}$ 1	2.870000$_{10}$ 1	1.108000$_{10}$ 3	4.650000$_{10}$ 2	1.849000$_{10}$ 3	4.230000$_{10}$ 2	3.180000$_{10}$ 2
5.000000$_{10}$ 2	1.831000$_{10}$ 2	1.204000$_{10}$ 2	3.676000$_{10}$ 3	2.420000$_{10}$ 3	9.623000$_{10}$ 3	3.726000$_{10}$ 3	2.221000$_{10}$ 3
3.360000$_{10}$ 2	1.103000$_{10}$ 2	7.470000$_{10}$ 1	4.685000$_{10}$ 3	3.170000$_{10}$ 3	7.484000$_{10}$ 3	1.759000$_{10}$ 3	1.040000$_{10}$ 3
2.640000$_{10}$ 2	7.110000$_{10}$ 1	4.040000$_{10}$ 1	2.470000$_{10}$ 2	6.900000$_{10}$ 1	1.426000$_{10}$ 3	7.370000$_{10}$ 2	4.420000$_{10}$ 2
4.300000$_{10}$ 2	2.930000$_{10}$ 2	2.078000$_{10}$ 2	5.360000$_{10}$ 2	5.410000$_{10}$ 2	1.935000$_{10}$ 3	1.107000$_{10}$ 3	2.920000$_{10}$ 2
2.940000$_{10}$ 2	1.222000$_{10}$ 2	5.820000$_{10}$ 1	4.365000$_{10}$ 3	4.202000$_{10}$ 3	7.615000$_{10}$ 3	2.336000$_{10}$ 3	9.140000$_{10}$ 2
1.660000$_{10}$ 2	4.400000$_{10}$ 1	2.400000$_{10}$ 1	1.080000$_{10}$ 2	1.000000$_{10}$ 1	4.900000$_{10}$ 2	2.950000$_{10}$ 2	8.700000$_{10}$ 1
5.610000$_{10}$ 2	2.258000$_{10}$ 2	1.357000$_{10}$ 2	6.000000$_{10}$ 2	3.410000$_{10}$ 2	2.016000$_{10}$ 3	1.024000$_{10}$ 3	3.920000$_{10}$ 2
3.250000$_{10}$ 2	1.745000$_{10}$ 2	8.670000$_{10}$ 1	8.180000$_{10}$ 2	6.950000$_{10}$ 2	2.062000$_{10}$ 3	7.870000$_{10}$ 2	4.570000$_{10}$ 2
1.930000$_{10}$ 2	1.071000$_{10}$ 2	3.820000$_{10}$ 1	4.400000$_{10}$ 1	1.240000$_{10}$ 2	3.760000$_{10}$ 2	1.830000$_{10}$ 2	1.490000$_{10}$ 2
3.470000$_{10}$ 2	2.426000$_{10}$ 2	1.320000$_{10}$ 2	2.950000$_{10}$ 2	2.540000$_{10}$ 2	1.109000$_{10}$ 3	5.540000$_{10}$ 2	2.700000$_{10}$ 2
6.400000$_{10}$ 1	1.450000$_{10}$ 1	7.300000$_{10}$ 0	1.400000$_{10}$ 1	1.400000$_{10}$ 1	1.360000$_{10}$ 2	1.110000$_{10}$ 2	1.100000$_{10}$ 1
5.950000$_{10}$ 2	5.800000$_{10}$ 1	3.310000$_{10}$ 1	2.800000$_{10}$ 1	1.600000$_{10}$ 1	1.310000$_{10}$ 2	7.400000$_{10}$ 1	2.900000$_{10}$ 1
3.570000$_{10}$ 2	2.138000$_{10}$ 2	1.298000$_{10}$ 2	6.830000$_{10}$ 2	1.930000$_{10}$ 2	1.727000$_{10}$ 3	6.770000$_{10}$ 2	3.670000$_{10}$ 2
2.940000$_{10}$ 2	5.930000$_{10}$ 1	2.890000$_{10}$ 1	4.700000$_{10}$ 1	3.000000$_{10}$ 1	1.660000$_{10}$ 2	9.600000$_{10}$ 1	2.300000$_{10}$ 1
6.320000$_{10}$ 2	3.664000$_{10}$ 2	2.400000$_{10}$ 2	4.640000$_{10}$ 2	2.120000$_{10}$ 2	1.271000$_{10}$ 3	5.940000$_{10}$ 2	2.130000$_{10}$ 2
3.120000$_{10}$ 2	1.809000$_{10}$ 2	1.040000$_{10}$ 2	7.750000$_{10}$ 2	5.070000$_{10}$ 2	1.876000$_{10}$ 3	7.720000$_{10}$ 2	3.290000$_{10}$ 2

LOG. NATL. OF

I		C		K_0		K_{AR}		K_{A-PN}		GO		NO		L_E	
3.704500$_{10}$	4	9.824971$_{10}$	-1	4.204000$_{10}$	2	3.274000$_{10}$	2	6.129000$_{10}$	2	1.079372$_{10}$	1	9.364691$_{10}$	0	6.735780$_{10}$	0
4.747000$_{10}$	3	9.812500$_{10}$	-1	6.180000$_{10}$	1	1.275000$_{10}$	2	1.537000$_{10}$	2	8.589142$_{10}$	0	6.439350$_{10}$	0	3.446808$_{10}$	0
1.442900$_{10}$	4	9.884146$_{10}$	-1	3.570000$_{10}$	2	4.739000$_{10}$	2	7.037000$_{10}$	2	1.006036$_{10}$	1	9.101418$_{10}$	0	6.186826$_{10}$	0
8.184000$_{10}$	3	9.688841$_{10}$	-1	2.435000$_{10}$	2	3.097000$_{10}$	2	4.518000$_{10}$	2	9.587955$_{10}$	0	8.764678$_{10}$	0	6.112575$_{10}$	0
4.341000$_{10}$	3	9.863309$_{10}$	-1	6.380000$_{10}$	1	6.340000$_{10}$	1	9.820000$_{10}$	1	8.708640$_{10}$	0	7.446585$_{10}$	0	4.920711$_{10}$	0
1.458400$_{10}$	4	9.894302$_{10}$	-1	2.972000$_{10}$	2	2.874000$_{10}$	2	4.773000$_{10}$	2	1.021038$_{10}$	1	9.441452$_{10}$	0	7.088576$_{10}$	0
7.920000$_{10}$	2	9.921053$_{10}$	-1	3.390000$_{10}$	1	2.580000$_{10}$	1	4.870000$_{10}$	1	7.777793$_{10}$	0	7.374629$_{10}$	0	5.015954$_{10}$	0
5.455000$_{10}$	3	9.908000$_{10}$	-1	1.115000$_{10}$	2	1.030000$_{10}$	2	1.742000$_{10}$	2	9.342158$_{10}$	0	8.691819$_{10}$	0	6.205366$_{10}$	0
2.565000$_{10}$	3	9.889881$_{10}$	-1	6.030000$_{10}$	1	5.680000$_{10}$	1	9.590000$_{10}$	1	8.748464$_{10}$	0	8.225771$_{10}$	0	5.806038$_{10}$	0
2.006000$_{10}$	3	9.484848$_{10}$	-1	6.700000$_{10}$	1	5.990000$_{10}$	1	9.770000$_{10}$	1	8.324094$_{10}$	0	7.657283$_{10}$	0	5.523060$_{10}$	0
8.903000$_{10}$	3	9.886047$_{10}$	-1	2.614000$_{10}$	2	2.263000$_{10}$	2	3.466000$_{10}$	2	9.603733$_{10}$	0	8.685585$_{10}$	0	6.052324$_{10}$	0
3.003000$_{10}$	3	9.925170$_{10}$	-1	7.210000$_{10}$	1	1.003000$_{10}$	2	1.361000$_{10}$	2	8.738094$_{10}$	0	8.081166$_{10}$	0	5.676069$_{10}$	0
1.416000$_{10}$	3	9.885542$_{10}$	-1	4.320000$_{10}$	1	4.930000$_{10}$	1	6.320000$_{10}$	1	7.843064$_{10}$	0	7.031741$_{10}$	0	5.100476$_{10}$	0
8.929000$_{10}$	3	9.823529$_{10}$	-1	1.367000$_{10}$	2	1.542000$_{10}$	2	2.268000$_{10}$	2	9.584452$_{10}$	0	8.631949$_{10}$	0	6.311916$_{10}$	0
3.777000$_{10}$	3	9.566154$_{10}$	-1	1.126000$_{10}$	2	1.772000$_{10}$	2	2.004000$_{10}$	2	8.694000$_{10}$	0	7.691657$_{10}$	0	5.739471$_{10}$	0
3.603000$_{10}$	3	9.803109$_{10}$	-1	3.090000$_{10}$	1	8.200000$_{10}$	1	9.980000$_{10}$	1	8.582606$_{10}$	0	7.458763$_{10}$	0	5.242805$_{10}$	0
4.646000$_{10}$	3	9.829971$_{10}$	-1	1.906000$_{10}$	2	2.516000$_{10}$	2	3.012000$_{10}$	2	9.035749$_{10}$	0	8.230044$_{10}$	0	5.832176$_{10}$	0
1.161000$_{10}$	3	9.812500$_{10}$	-1	1.390000$_{10}$	1	1.530000$_{10}$	1	2.110000$_{10}$	1	7.475906$_{10}$	0	6.403574$_{10}$	0	4.139955$_{10}$	0
4.761000$_{10}$	3	9.847059$_{10}$	-1	7.910000$_{10}$	1	6.900000$_{10}$	1	1.040000$_{10}$	2	9.088850$_{10}$	0	8.317522$_{10}$	0	6.373149$_{10}$	0
3.332000$_{10}$	3	9.837535$_{10}$	-1	1.403000$_{10}$	2	1.425000$_{10}$	2	2.243000$_{10}$	2	8.915835$_{10}$	0	8.322880$_{10}$	0	5.861356$_{10}$	0
3.605000$_{10}$	3	9.802721$_{10}$	-1	7.930000$_{10}$	1	6.700000$_{10}$	1	1.097000$_{10}$	2	8.710455$_{10}$	0	7.808323$_{10}$	0	5.663655$_{10}$	0
7.479000$_{10}$	3	9.925633$_{10}$	-1	2.168000$_{10}$	2	2.162000$_{10}$	2	3.432000$_{10}$	2	9.638806$_{10}$	0	8.970813$_{10}$	0	6.441425$_{10}$	0
3.831000$_{10}$	3	9.833333$_{10}$	-1	7.880000$_{10}$	1	1.116000$_{10}$	2	1.557000$_{10}$	2	8.865170$_{10}$	0	8.086410$_{10}$	0	5.726196$_{10}$	0

LOG. NATL. OF

L_M	L_F	K_A	K_{AN}	KL_{FR}	K_P	K_{PN}	R_{62}
6.164787⏨ 0	5.903453⏨ 0	6.838405⏨ 0	6.406220⏨ 0	6.753438⏨ 0	6.239496⏨ 0	5.768633⏨ 0	6.888572⏨ 0
3.258097⏨ 0	1.686399⏨ 0	5.552184⏨ 0	4.869839⏨ 0	3.465736⏨ 0	5.278115⏨ 0	4.645352⏨ 0	6.637258⏨ 0
5.850765⏨ 0	4.933034⏨ 0	7.143855⏨ 0	6.675066⏨ 0	6.198479⏨ 0	6.812675⏨ 0	6.332569⏨ 0	8.717846⏨ 0
6.005614⏨ 0	3.824284⏨ 0	6.967815⏨ 0	6.623002⏨ 0	6.144186⏨ 0	6.707351⏨ 0	6.413623⏨ 0	6.843750⏨ 0
4.702297⏨ 0	3.292126⏨ 0	5.175019⏨ 0	4.730921⏨ 0	4.934474⏨ 0	4.727388⏨ 0	4.364372⏨ 0	6.437752⏨ 0
6.892946⏨ 0	5.360823⏨ 0	6.672539⏨ 0	6.220590⏨ 0	7.099202⏨ 0	6.200915⏨ 0	5.746523⏨ 0	7.914252⏨ 0
4.554929⏨ 0	4.019980⏨ 0	4.348987⏨ 0	3.943522⏨ 0	5.023881⏨ 0	3.772761⏨ 0	3.356897⏨ 0	7.010312⏨ 0
5.799093⏨ 0	5.109575⏨ 0	5.685619⏨ 0	5.255410⏨ 0	6.214608⏨ 0	5.210032⏨ 0	4.790820⏨ 0	8.209580⏨ 0
5.238567⏨ 0	4.969119⏨ 0	5.139322⏨ 0	4.734443⏨ 0	5.817111⏨ 0	4.703204⏨ 0	4.313480⏨ 0	8.452121⏨ 0
5.471009⏨ 0	2.541602⏨ 0	4.927978⏨ 0	4.359270⏨ 0	5.575949⏨ 0	4.264087⏨ 0	3.698830⏨ 0	5.509388⏨ 0
5.907267⏨ 0	4.050044⏨ 0	6.317886⏨ 0	5.793318⏨ 0	6.063785⏨ 0	5.680173⏨ 0	5.336576⏨ 0	6.284134⏨ 0
5.516247⏨ 0	3.763523⏨ 0	5.269403⏨ 0	4.543295⏨ 0	5.683580⏨ 0	4.805659⏨ 0	4.063885⏨ 0	8.381373⏨ 0
4.984291⏨ 0	2.890372⏨ 0	4.468204⏨ 0	3.634951⏨ 0	5.111988⏨ 0	3.784190⏨ 0	3.178054⏨ 0	4.682131⏨ 0
5.888878⏨ 0	5.247550⏨ 0	5.893024⏨ 0	5.338979⏨ 0	6.329721⏨ 0	5.419650⏨ 0	4.910447⏨ 0	6.396930⏨ 0
4.969119⏨ 0	5.117994⏨ 0	5.659831⏨ 0	4.699571⏨ 0	5.783825⏨ 0	5.161925⏨ 0	4.462454⏨ 0	6.706862⏨ 0
4.486387⏨ 0	4.609162⏨ 0	4.927254⏨ 0	4.025352⏨ 0	5.262690⏨ 0	4.673763⏨ 0	3.642836⏨ 0	3.784190⏨ 0
5.036303⏨ 0	5.232178⏨ 0	6.071200⏨ 0	5.201806⏨ 0	5.849325⏨ 0	5.491414⏨ 0	4.882802⏨ 0	5.686975⏨ 0
3.594569⏨ 0	3.273364⏨ 0	3.346389⏨ 0	2.572612⏨ 0	4.158883⏨ 0	2.674149⏨ 0	1.987874⏨ 0	2.639057⏨ 0
5.066385⏨ 0	6.057486⏨ 0	4.920711⏨ 0	4.220977⏨ 0	6.388561⏨ 0	4.060443⏨ 0	3.499533⏨ 0	3.332205⏨ 0
5.595083⏨ 0	4.407938⏨ 0	5.869579⏨ 0	5.354698⏨ 0	5.877736⏨ 0	5.365041⏨ 0	4.865995⏨ 0	6.526495⏨ 0
5.436774⏨ 0	4.069027⏨ 0	4.931592⏨ 0	4.271095⏨ 0	5.683580⏨ 0	4.082609⏨ 0	3.363842⏨ 0	3.850148⏨ 0
6.011022⏨ 0	5.390897⏨ 0	6.368530⏨ 0	5.905362⏨ 0	6.448889⏨ 0	5.903726⏨ 0	5.480639⏨ 0	6.139885⏨ 0
5.224671⏨ 0	4.795791⏨ 0	5.559527⏨ 0	4.997888⏨ 0	5.743003⏨ 0	5.197944⏨ 0	4.644391⏨ 0	6.652863⏨ 0

LOG. NATL. OF

R_{56}		T_{ST}		F		M		I		C		K_0		K_{AR}	
6.113682$_{10}$	0	7.928406$_{10}$	0	7.513164$_{10}$	0	6.021023$_{10}$	0	1.051989$_{10}$	1	-1.765790$_{10}$	-2	6.041207$_{10}$	0	5.791183$_{10}$	0
6.135565$_{10}$	0	7.559559$_{10}$	0	6.845880$_{10}$	0	5.375278$_{10}$	0	8.465268$_{10}$	0	-1.892801$_{10}$	-2	4.123903$_{10}$	0	4.848116$_{10}$	0
8.283999$_{10}$	0	9.663007$_{10}$	0	8.807771$_{10}$	0	7.818832$_{10}$	0	9.576995$_{10}$	0	-1.165300$_{10}$	-2	5.877736$_{10}$	0	6.160996$_{10}$	0
6.182085$_{10}$	0	8.235095$_{10}$	0	7.666222$_{10}$	0	5.697093$_{10}$	0	9.009936$_{10}$	0	-3.161026$_{10}$	-2	5.495117$_{10}$	0	5.735604$_{10}$	0
6.045005$_{10}$	0	7.537430$_{10}$	0	6.799056$_{10}$	0	5.958425$_{10}$	0	8.375860$_{10}$	0	-1.376335$_{10}$	-2	4.155753$_{10}$	0	4.149464$_{10}$	0
7.534228$_{10}$	0	9.428190$_{10}$	0	8.778480$_{10}$	0	8.072467$_{10}$	0	9.587680$_{10}$	0	-1.062603$_{10}$	-2	5.694405$_{10}$	0	5.660875$_{10}$	0
6.142037$_{10}$	0	7.522400$_{10}$	0	6.047372$_{10}$	0	5.762051$_{10}$	0	6.674561$_{10}$	0	-7.926065$_{10}$	-3	3.523415$_{10}$	0	3.250374$_{10}$	0
7.791523$_{10}$	0	9.171911$_{10}$	0	8.223091$_{10}$	0	7.705713$_{10}$	0	8.604288$_{10}$	0	-9.242581$_{10}$	-3	4.714025$_{10}$	0	4.634729$_{10}$	0
8.061487$_{10}$	0	8.920523$_{10}$	0	7.472501$_{10}$	0	6.946976$_{10}$	0	7.849714$_{10}$	0	-1.107298$_{10}$	-2	4.099332$_{10}$	0	4.039536$_{10}$	0
4.234107$_{10}$	0	7.262629$_{10}$	0	6.602588$_{10}$	0	6.091310$_{10}$	0	7.603898$_{10}$	0	-5.288946$_{10}$	-2	4.204693$_{10}$	0	4.092677$_{10}$	0
6.293419$_{10}$	0	7.567863$_{10}$	0	7.009409$_{10}$	0	5.676754$_{10}$	0	9.094144$_{10}$	0	-1.146077$_{10}$	-2	5.566052$_{10}$	0	5.421862$_{10}$	0
8.343316$_{10}$	0	8.937875$_{10}$	0	7.756195$_{10}$	0	6.817831$_{10}$	0	8.007367$_{10}$	0	-7.511131$_{10}$	-3	4.278054$_{10}$	0	4.608166$_{10}$	0
2.302585$_{10}$	0	6.194405$_{10}$	0	5.686975$_{10}$	0	4.465908$_{10}$	0	7.255591$_{10}$	0	-1.151179$_{10}$	-2	3.765840$_{10}$	0	3.897924$_{10}$	0
5.831882$_{10}$	0	7.608871$_{10}$	0	6.931472$_{10}$	0	5.971262$_{10}$	0	9.097060$_{10}$	0	-1.780462$_{10}$	-2	4.917789$_{10}$	0	5.038250$_{10}$	0
6.543912$_{10}$	0	7.631432$_{10}$	0	6.668228$_{10}$	0	6.124683$_{10}$	0	8.236685$_{10}$	0	-4.435387$_{10}$	-2	4.723842$_{10}$	0	5.177279$_{10}$	0
4.820282$_{10}$	0	5.929589$_{10}$	0	5.209486$_{10}$	0	5.003946$_{10}$	0	8.189522$_{10}$	0	-1.988553$_{10}$	-2	3.430756$_{10}$	0	4.406719$_{10}$	0
5.537334$_{10}$	0	7.011214$_{10}$	0	6.317165$_{10}$	0	5.598422$_{10}$	0	8.443762$_{10}$	0	-1.714909$_{10}$	-2	5.250177$_{10}$	0	5.527841$_{10}$	0
2.639057$_{10}$	0	4.912655$_{10}$	0	4.709530$_{10}$	0	2.397895$_{10}$	0	7.057037$_{10}$	0	-1.892801$_{10}$	-2	2.631889$_{10}$	0	2.727853$_{10}$	0
2.772589$_{10}$	0	4.875197$_{10}$	0	4.304065$_{10}$	0	3.367296$_{10}$	0	8.468213$_{10}$	0	-1.541228$_{10}$	-2	4.370713$_{10}$	0	4.234107$_{10}$	0
5.262690$_{10}$	0	7.454141$_{10}$	0	6.517671$_{10}$	0	5.905362$_{10}$	0	8.111328$_{10}$	0	-1.637992$_{10}$	-2	4.943783$_{10}$	0	4.959342$_{10}$	0
3.401197$_{10}$	0	5.111988$_{10}$	0	4.564348$_{10}$	0	3.135494$_{10}$	0	8.190077$_{10}$	0	-1.992508$_{10}$	-2	4.373238$_{10}$	0	4.204693$_{10}$	0
5.356586$_{10}$	0	7.147559$_{10}$	0	6.386879$_{10}$	0	5.361292$_{10}$	0	8.919854$_{10}$	0	-7.464499$_{10}$	-3	5.378975$_{10}$	0	5.376204$_{10}$	0
6.228511$_{10}$	0	7.536897$_{10}$	0	6.648985$_{10}$	0	5.796058$_{10}$	0	8.250881$_{10}$	0	-1.680712$_{10}$	-2	4.366913$_{10}$	0	4.714921$_{10}$	0

LOG. NATL. OF K_{A-PN}	
.418202	0
.035003	0
.556352	0
.113240	0
.587006	0
.168145	0
.885679	0
.160204	0
.563306	0
.581902	0
.848171	0
.913390	0
.146304	0
.424069	0
.300315	0
.603168	0
.707774	0
.049273	0
.644391	0
.412984	0
.697749	0
.838313	0
.047931	0

RMAL MATRIX

.000	0.652
	1.000

```
EGRESSION NO.   1
IAGONAL ELEMENTS OF NORMAL INVERSE

1.738378₁₀  0 1.738378₁₀  0
EPENDENT VARIABLE NO  22

UMBER   COEFFICIENT    STANDARD  ERROR        MEAN                F-VALUE

 22        DEPENDENT  VARIABLE              8.096874₁₀  0
 23     7.333339₁₀ -1     5.618194₁₀ -2    5.704464₁₀  0     1.703766₁₀  2
 26     3.236008₁₀ -1     4.937614₁₀ -2    5.567602₁₀  0     4.295216₁₀  1
  0     2.111917₁₀  0

NALYSIS OF VARIANCE TABLE

                SUMS OF SQUARES   DZZ.FZZ.   MEANZZ SQUARESZZ       FZZ-RATIOZZ
UE REGRESSION     1.477371₁₀  1       2   7.386854₁₀  0     2.823420₁₀  2
ESIDUAL           5.232558₁₀ -1      20    2.616279₁₀ -2
OTAL(CORRECT)  1.529696₁₀  1      22

R SQUARED        R-BAR  SQUARED              R
0.965793           0.962373           0.982748

ON-NEUMANN  RATIO      1.955923₁₀  0

ARIANCE-COVARIANCE   MATRIX

3.156₁₀ -3  -1.808₁₀ -3     23

            2.438₁₀ -3     26

ORMAL MATRIX
1.000   0.582

        1.000
```

GRESSION NO. 2 (7.1.4)
AGONAL ELEMENTS OF NORMAL INVERSE

.510973ₘ 0 1.510973ₘ 0
PENDENT VARIABLE NO 22

MBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
22	DEPENDENT VARIABLE		8.096874ₘ 0	
23	7.735208ₘ -1	5.228975ₘ -2	5.704464ₘ 0	2.188320ₘ 2
29	2.774107ₘ -1	4.222331ₘ -2	5.052900ₘ 0	4.316600ₘ 1
0	2.282624ₘ 0			

ALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
E REGRESSION	1.477548ₘ 1	2	7.387740ₘ 0	2.833351ₘ 2
SIDUAL	5.214844ₘ -1	20	2.607422ₘ -2	
TAL(CORRECT)	1.529696ₘ 1	22		

SQUARED	R-BAR SQUARED	R
.965909	0.962500	0.982807

N-NEUMANN RATIO 1.651222ₘ 0

RIANCE-COVARIANCE MATRIX

.734ₘ -3	-1.284ₘ -3	23
	1.783ₘ -3	29

RMAL MATRIX

.000	0.659	0.613
	1.000	0.926
		1.000

```
EGRESSION NO.   3
IAGONAL ELEMENTS OF NORMAL INVERSE     (6.1.8)

1.768642⏨  0 7.714279⏨  0 6.989381⏨  0
EPENDENT VARIABLE NO  22

UMBER   COEFFICIENT    STANDARD  ERROR        MEAN                F-VALUE

  22        DEPENDENT  VARIABLE             8.096874⏨  0
  23      7.096759⏨ -1     4.141488⏨ -2     5.704464⏨  0     2.936347⏨  2
  27      4.561473⏨ -1     6.919314⏨ -2     4.972965⏨  0     4.345943⏨  1
  39     -1.753540⏨ -1     7.885702⏨ -2     4.724292⏨  0     4.944821⏨  0
   0      2.608573⏨  0


NALYSIS OF VARIANCE TABLE

                   SUMS OF SQUARES   DZZ.FZZ.   MEANZZ SQUARESZZ       FZZ-RATIOZZ
UE REGRESSION     1.503147⏨  1        3   5.010489⏨  0     3.585688⏨  2
ESIDUAL           2.654980⏨ -1       19    1.397358⏨ -2
OTAL(CORRECT)  1.529696⏨  1       22


R  SQUARED          R-BAR  SQUARED              R
0.982644              0.979903              0.991284

ON-NEUMANN  RATIO       2.304832⏨  0

ARIANCE-COVARIANCE   MATRIX

1.715⏨ -3   -8.789⏨ -4   -3.314⏨ -5     23

            4.788⏨ -3   -4.790⏨ -3     27

                         6.218⏨ -3     39


ORMAL MATRIX
1.000   0.594   0.681

        1.000   0.954

                1.000
```

EGRESSION NO. 4 (7.1.13)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.994905$_{10}$ 0 1.202201$_{10}$ 1 1.450951$_{10}$ 1
EPENDENT VARIABLE NO 22

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
22	DEPENDENT VARIABLE		8.096874$_{10}$ 0	
23	7.733066$_{10}$ -1	5.555495$_{10}$ -2	5.704464$_{10}$ 0	1.937573$_{10}$ 2
30	3.221376$_{10}$ -1	1.021256$_{10}$ -1	4.510888$_{10}$ 0	9.949773$_{10}$ 0
40	-7.762323$_{10}$ -2	1.430461$_{10}$ -1	5.117516$_{10}$ 0	2.944636$_{10}$ -1
0	2.629686$_{10}$ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.487341$_{10}$ 1	3	4.957803$_{10}$ 0	2.223982$_{10}$ 2
ESIDUAL	4.235567$_{10}$ -1	19	2.229246$_{10}$ -2	
OTAL(CORRECT)	1.529696$_{10}$ 1	22		

R SQUARED	R-BAR SQUARED	R
0.972311	0.967939	0.986058

ON-NEUMANN RATIO 1.946918$_{10}$ 0

RIANCE-COVARIANCE MATRIX

3.086$_{10}$ -3	1.457$_{10}$ -3	-3.778$_{10}$ -3	23
	1.043$_{10}$ -2	-1.364$_{10}$ -2	30
		2.046$_{10}$ -2	40

RMAL MATRIX

1.000	0.652	0.105
	1.000	0.046
		1.000

REGRESSION NO. 5
DIAGONAL ELEMENTS OF NORMAL INVERSE (8.1.2)

1.755412₁₀ 0 1.739885₁₀ 0 1.011936₁₀ 0

DEPENDENT VARIABLE NO 22

NUMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
22	DEPENDENT VARIABLE		8.096874₁₀ 0	
23	7.181689₁₀ -1	4.591001₁₀ -2	5.704464₁₀ 0	2.447025₁₀ 2
26	3.275659₁₀ -1	4.016970₁₀ -2	5.567602₁₀ 0	6.649672₁₀ 1
37	8.443049₁₀ 0	2.517869₁₀ 0	-1.782449₁₀ -2	1.124430₁₀ 1
0	2.326842₁₀ 0			

ANALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
DUE REGRESSION	1.496825₁₀ 1	3	4.989415₁₀ 0	2.883893₁₀ 2
RESIDUAL	3.287184₁₀ -1	19	1.730097₁₀ -2	
TOTAL(CORRECT)	1.529696₁₀ 1	22		

R SQUARED	R-BAR SQUARED	R
0.978511	0.975118	0.989197

VON-NEUMANN RATIO 1.722137₁₀ 0

VARIANCE-COVARIANCE MATRIX

2.108₁₀ -3	-1.201₁₀ -3	-1.139₁₀ -2	23
	1.614₁₀ -3	2.977₁₀ -3	26
		6.340₁₀ 0	37

NORMAL MATRIX

1.000	0.659	0.105	0.613
	1.000	0.090	0.926
		1.000	-0.010
			1.000

EGRESSION NO. 6
IAGONAL ELEMENTS OF NORMAL INVERSE (8.1.12)

1.776087» 0 8.158056» 0 1.078787» 0 7.451520» 0

EPENDENT VARIABLE NO 22

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
22	DEPENDENT	VARIABLE	8.096874» 0	
23	7.023601» -1	3.329845» -2	5.704464» 0	4.449095» 2
27	4.109632» -1	5.709055» -2	4.972965» 0	5.181762» 1
37	6.361071» 0	1.874556» 0	-1.782449» -2	1.151499» 1
39	-1.201469» -1	6.532794» -2	4.724292» 0	3.382419» 0
0	2.727573» 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.513505» 1	4	3.783762» 0	4.206348» 2
ESIDUAL	1.619165» -1	18	8.995361» -3	
OTAL(CORRECT)	1.529696» 1	22		

R SQUARED	R-BAR SQUARED	R
0.989415	0.987063	0.994693

ON-NEUMANN RATIO 2.016869» 0

ARIANCE-COVARIANCE MATRIX

1.109» -3	-5.371» -4	-4.041» -3	-5.641» -5	23
	3.259» -3	-2.496» -2	-3.300» -3	27
		3.514» 0	3.050» -2	37
			4.268» -3	39

ORMAL MATRIX

1.000	0.571	0.704
	1.000	0.430
		1.000

EGRESSION NO. 7 (9.1.2)
IAGONAL ELEMENTS OF NORMAL INVERSE

2.402672₁₀ 0 1.488401₁₀ 0 1.985106₁₀ 0
EPENDENT VARIABLE NO 22

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
22	DEPENDENT VARIABLE		8.096874₁₀ 0	
24	5.416664₁₀ -1	5.952973₁₀ -2	5.289352₁₀ 0	8.279346₁₀ 1
25	2.234035₁₀ -1	3.471226₁₀ -2	4.371553₁₀ 0	4.142040₁₀ 1
26	2.897227₁₀ -1	4.808346₁₀ -2	5.567602₁₀ 0	3.630561₁₀ 1
0	2.642128₁₀ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.488415₁₀ 1	3	4.961383₁₀ 0	2.283500₁₀ 2
ESIDUAL	4.128149₁₀ -1	19	2.172710₁₀ -2	
OTAL(CORRECT)	1.529696₁₀ 1	22		

R SQUARED	R-BAR SQUARED	R
0.973013	0.968752	0.986414

ON-NEUMANN RATIO 1.422698₁₀ 0

ARIANCE-COVARIANCE MATRIX

3.544₁₀ -3	-8.661₁₀ -4	-1.769₁₀ -3	24
	1.205₁₀ -3	-7.997₁₀ -5	25
		2.312₁₀ -3	26

ORMAL MATRIX

1.000	0.652	0.339
	1.000	0.595
		1.000

EGRESSION NO. 8 (10.1.1)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.749830$_{10}$ 0 2.399651$_{10}$ 0 1.559295$_{10}$ 0
EPENDENT VARIABLE NO 22

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
22	DEPENDENT	VARIABLE	8.096874$_{10}$ 0	
23	7.410833$_{10}$ -1	5.349284$_{10}$ -2	5.704464$_{10}$ 0	1.919299$_{10}$ 2
26	2.718477$_{10}$ -1	5.505443$_{10}$ -2	5.567602$_{10}$ 0	2.438186$_{10}$ 1
31	4.401571$_{10}$ -2	2.457986$_{10}$ -2	6.247134$_{10}$ 0	3.206687$_{10}$ 0
0	2.080880$_{10}$ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.484927$_{10}$ 1	3	4.949756$_{10}$ 0	2.100649$_{10}$ 2
ESIDUAL	4.476967$_{10}$ -1	19	2.356298$_{10}$ -2	
OTAL(CORRECT)	1.529696$_{10}$ 1	22		

R SQUARED	R-BAR SQUARED	R
0.970733	0.966112	0.985258

ON-NEUMANN RATIO 2.096581$_{10}$ 0

ARIANCE-COVARIANCE MATRIX

2.861$_{10}$ -3	-1.753$_{10}$ -3	1.064$_{10}$ -4	23
	3.031$_{10}$ -3	-7.104$_{10}$ -4	26
		6.042$_{10}$ -4	31

RMAL MATRIX

1.000	0.652	0.312
	1.000	0.580
		1.000

EGRESSION NO. 9 (Not discussed in the the text)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.758582$_{10}$ 0 2.391393$_{10}$ 0 1.523498$_{10}$ 0
EPENDENT VARIABLE NO 22

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
22	DEPENDENT VARIABLE		8.096874$_{10}$ 0	
23	7.450112$_{10}$ -1	5.231157$_{10}$ -2	5.704464$_{10}$ 0	2.028290$_{10}$ 2
26	2.652567$_{10}$ -1	5.361204$_{10}$ -2	5.567602$_{10}$ 0	2.447982$_{10}$ 1
32	4.693688$_{10}$ -2	2.253800$_{10}$ -2	5.732917$_{10}$ 0	4.337081$_{10}$ 0
0	2.101056$_{10}$ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.487095$_{10}$ 1	3	4.956984$_{10}$ 0	2.210803$_{10}$ 2
ESIDUAL	4.260113$_{10}$ -1	19	2.242165$_{10}$ -2	
OTAL(CORRECT)	1.529696$_{10}$ 1	22		

R SQUARED	R-BAR SQUARED	R
0.972151	0.967753	0.985977

ON-NEUMANN RATIO 1.847180$_{10}$ 0

ARIANCE-COVARIANCE MATRIX

2.737$_{10}$ -3	-1.706$_{10}$ -3	1.264$_{10}$ -4	23
	2.874$_{10}$ -3	-6.314$_{10}$ -4	26
		5.080$_{10}$ -4	32

ORMAL MATRIX

1.000	0.652	0.642
	1.000	0.874
		1.000

EGRESSION NO. 10 (6.1.6)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.807864₁₀ 0 4.502081₁₀ 0 4.404396₁₀ 0
EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT VARIABLE		8.996497₁₀ 0	
23	2.272754₁₀ -1	3.359076₁₀ -2	5.704464₁₀ 0	4.577889₁₀ 1
26	1.393776₁₀ -1	4.658691₁₀ -2	5.567602₁₀ 0	8.950720₁₀ 0
36	6.239299₁₀ -1	4.922252₁₀ -2	8.416940₁₀ 0	1.606734₁₀ 2
0	1.672433₁₀ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.359629₁₀ 1	3	4.532096₁₀ 0	5.039537₁₀ 2
ESIDUAL	1.708685₁₀ -1	19	8.993081₁₀ -3	
OTAL(CORRECT)	1.376716₁₀ 1	22		

R SQUARED	R-BAR SQUARED	R
0.987589	0.985629	0.993775

ON-NEUMANN RATIO 1.357775₁₀ 0

ARIANCE-COVARIANCE MATRIX

.128₁₀ -3	-3.811₁₀ -4	-3.242₁₀ -4	23
	2.170₁₀ -3	-1.797₁₀ -3	26
		2.423₁₀ -3	36

ORMAL MATRIX

.000	0.582	0.642
	1.000	0.843
		1.000

EGRESSION NO. 11 (7.1.9)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.7171010 0 3.4921720 0 3.9305760 0
EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT VARIABLE		8.9964970 0	
23	2.4207410 -1	3.2591760 -2	5.7044640 0	5.5167210 1
29	1.1383720 -1	3.7531280 -2	5.0529000 0	9.1998630 0
36	6.3354850 -1	4.6293690 -2	8.4169400 0	1.8729070 2
0	1.7078470 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.3597800 1	3	4.5325990 0	5.0850220 2
ESIDUAL	1.6935890 -1	19	8.9136280 -3	
OTAL(CORRECT)	1.3767160 1	22		

R SQUARED	R-BAR SQUARED	R
0.987698	0.985756	0.993830

ON-NEUMANN RATIO 1.1781290 0

ARIANCE-COVARIANCE MATRIX

1.0620 -3	-1.1970 -4	-5.2280 -4	23
	1.4090 -3	-1.3090 -3	29
		2.1430 -3	36

ORMAL MATRIX

1.000	0.659	0.642	0.613
	1.000	0.858	0.926
		1.000	0.865
			1.000

EGRESSION NO. 12 (6.1.7)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.849229⏨ 0 8.158210⏨ 0 4.560269⏨ 0 8.105111⏨ 0

EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT	VARIABLE	8.996497⏨ 0	
23	2.110667⏨ -1	2.413821⏨ -2	5.704464⏨ 0	7.645911⏨ 1
27	2.363545⏨ -1	4.055890⏨ -2	4.972965⏨ 0	3.395906⏨ 1
36	6.412238⏨ -1	3.558679⏨ -2	8.416940⏨ 0	3.246696⏨ 2
39	-1.359439⏨ -1	4.840317⏨ -2	4.724292⏨ 0	7.888088⏨ 0
0	1.862189⏨ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.368544⏨ 1	4	3.421359⏨ 0	7.536062⏨ 2
ESIDUAL	8.171970⏨ -2	18	4.539983⏨ -3	
OTAL(CORRECT)	1.376716⏨ 1	22		

R SQUARED	R-BAR SQUARED	R
0.994064	0.992745	0.997028

ON-NEUMANN RATIO 1.772970⏨ 0

ARIANCE-COVARIANCE MATRIX

5.827⏨ -4	-2.379⏨ -4	-1.793⏨ -4	7.973⏨ -5	23
	1.645⏨ -3	-3.367⏨ -4	-1.386⏨ -3	27
		1.266⏨ -3	-6.391⏨ -4	36
			2.343⏨ -3	39

ORMAL MATRIX

1.000	0.594	0.642	0.681
	1.000	0.827	0.954
		1.000	0.891
			1.000

GRESSION NO. 13 (Not discussed in the text)
IAGONAL ELEMENTS OF NORMAL INVERSE

2.003193⏨ 0 1.230755⏨ 1 5.038265⏨ 0 2.050604⏨ 1

EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT	VARIABLE	8.996497⏨ 0	
23	2.478991⏨ -1	3.229416⏨ -2	5.704464⏨ 0	5.892531⏨ 1
30	1.719309⏨ -1	5.994227⏨ -2	4.510888⏨ 0	8.226998⏨ 0
36	6.565877⏨ -1	4.808249⏨ -2	8.416940⏨ 0	1.864711⏨ 2
40	-1.064210⏨ -1	9.864872⏨ -2	5.117516⏨ 0	1.163783⏨ 0
0	1.824957⏨ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.363213⏨ 1	4	3.408032⏨ 0	4.543009⏨ 2
ESIDUAL	1.350307⏨ -1	18	7.501705⏨ -3	
OTAL(CORRECT)	1.376716⏨ 1	22		

R SQUARED	R-BAR SQUARED	R
0.990192	0.988012	0.995084

ON-NEUMANN RATIO 1.294112⏨ 0

ARIANCE-COVARIANCE MATRIX

1.043⏨ -3	4.712⏨ -4	-9.988⏨ -5	-1.161⏨ -3	23
	3.593⏨ -3	4.390⏨ -4	-5.077⏨ -3	30
		2.312⏨ -3	-2.565⏨ -3	36
			9.732⏨ -3	40

ORMAL MATRIX

1.000	0.652	0.642	0.105
	1.000	0.874	0.046
		1.000	0.100
			1.000

EGRESSION NO. 14 (8.1.6)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.818440$_{10}$ 0 4.549767$_{10}$ 0 4.455640$_{10}$ 0 1.023710$_{10}$ 0

EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT	VARIABLE	8.996497$_{10}$ 0	
23	2.211315$_{10}$ -1	2.893790$_{10}$ -2	5.704464$_{10}$ 0	5.839385$_{10}$ 1
26	1.508436$_{10}$ -1	4.022838$_{10}$ -2	5.567602$_{10}$ 0	1.406011$_{10}$ 1
36	6.112329$_{10}$ -1	4.252618$_{10}$ -2	8.416940$_{10}$ 0	2.065859$_{10}$ 2
37	4.366370$_{10}$ 0	1.568356$_{10}$ 0	-1.782449$_{10}$ -2	7.750894$_{10}$ 0
0	1.828341$_{10}$ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.364772$_{10}$ 1	4	3.411930$_{10}$ 0	5.141979$_{10}$ 2
ESIDUAL	1.194379$_{10}$ -1	18	6.635441$_{10}$ -3	
OTAL(CORRECT)	1.376716$_{10}$ 1	22		

R SQUARED	R-BAR SQUARED	R
0.991324	0.989397	0.995653

ON-NEUMANN RATIO 1.190186$_{10}$ 0

ARIANCE-COVARIANCE MATRIX

8.374$_{10}$ -4	-2.903$_{10}$ -4	-2.291$_{10}$ -4	-3.461$_{10}$ -3	23
	1.618$_{10}$ -3	-1.344$_{10}$ -3	6.459$_{10}$ -3	26
		1.808$_{10}$ -3	-7.153$_{10}$ -3	36
			2.460$_{10}$ 0	37

ORMAL MATRIX

1.000	0.659	0.642	0.105	0.613
	1.000	0.858	0.090	0.926
		1.000	0.100	0.865
			1.000	-0.010
				1.000

EGRESSION NO. 15 (Not discussed in the text)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.851437⏨ 0 8.492922⏨ 0 4.651531⏨ 0 1.100377⏨ 0
8.804013⏨ 0
EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT VARIABLE		8.996497⏨ 0	
23	2.091881⏨ -1	2.106076⏨ -2	5.704464⏨ 0	9.865655⏨ 1
27	2.178493⏨ -1	3.608503⏨ -2	4.972965⏨ 0	3.644671⏨ 1
36	6.298839⏨ -1	3.134017⏨ -2	8.416940⏨ 0	4.039414⏨ 2
37	3.029624⏨ 0	1.172813⏨ 0	-1.782449⏨ -2	6.672979⏨ 0
39	-1.039275⏨ -1	4.398904⏨ -2	4.724292⏨ 0	5.581771⏨ 0
0	1.963125⏨ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.370847⏨ 1	5	2.741695⏨ 0	7.942281⏨ 2
ESIDUAL	5.868441⏨ -2	17	3.452024⏨ -3	
OTAL(CORRECT)	1.376716⏨ 1	22		

R SQUARED	R-BAR SQUARED	R
0.995737	0.994484	0.997866

ON-NEUMANN RATIO 1.582495⏨ 0

ARIANCE-COVARIANCE MATRIX

4.436⏨ -4	-1.757⏨ -4	-1.332⏨ -4	-8.529⏨ -4	5.161⏨ -5	23
	1.302⏨ -3	-2.246⏨ -4	-8.402⏨ -3	-1.143⏨ -3	27
		9.822⏨ -4	-5.148⏨ -3	-5.403⏨ -4	36
			1.375⏨ 0	1.454⏨ -2	37
				1.935⏨ -3	39

NORMAL MATRIX

1.000	0.571	0.704	0.634
	1.000	0.430	0.515
		1.000	0.874
			1.000

EGRESSION NO. 16 (9.1.7)

IAGONAL ELEMENTS OF NORMAL INVERSE

2.422414$_{10}$ 0 1.662749$_{10}$ 0 5.309321$_{10}$ 0 4.745533$_{10}$ 0

EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT	VARIABLE	8.996497$_{10}$ 0	
24	1.649571$_{10}$ -1	3.709333$_{10}$ -2	5.289352$_{10}$ 0	1.977655$_{10}$ 1
25	7.340936$_{10}$ -2	2.276781$_{10}$ -2	4.371553$_{10}$ 0	1.039586$_{10}$ 1
26	1.306881$_{10}$ -1	4.879871$_{10}$ -2	5.567602$_{10}$ 0	7.172251$_{10}$ 0
36	6.213162$_{10}$ -1	4.928273$_{10}$ -2	8.416940$_{10}$ 0	1.589410$_{10}$ 2
0	1.845867$_{10}$ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.361655$_{10}$ 1	4	3.404138$_{10}$ 0	4.068511$_{10}$ 2
ESIDUAL	1.506066$_{10}$ -1	18	8.367036$_{10}$ -3	
OTAL(CORRECT)	1.376716$_{10}$ 1	22		

R SQUARED	R-BAR SQUARED	R
0.989060	0.986629	0.994515

ON-NEUMANN RATIO 1.228146$_{10}$ 0

ARIANCE-COVARIANCE MATRIX

1.376$_{10}$ -3	-3.582$_{10}$ -4	-8.105$_{10}$ -4	1.650$_{10}$ -4	24
	5.184$_{10}$ -4	2.539$_{10}$ -4	-3.633$_{10}$ -4	25
		2.381$_{10}$ -3	-1.903$_{10}$ -3	26
			2.429$_{10}$ -3	36

ORMAL MATRIX

1.000	0.652	0.339	0.642
	1.000	0.595	0.874
		1.000	0.366
			1.000

EGRESSION NO. 17 (11.4.12)
IAGONAL ELEMENTS OF NORMAL INVERSE

1.807891⏨ 0 7.003976⏨ 0 1.835359⏨ 0 5.184168⏨ 0

EPENDENT VARIABLE NO 21

UMBER	COEFFICIENT	STANDARD ERROR	MEAN	F-VALUE
21	DEPENDENT	VARIABLE	8.996497⏨ 0	
23	2.275946⏨ -1	2.847070⏨ -2	5.704464⏨ 0	6.390393⏨ 1
26	5.381960⏨ -2	4.924983⏨ -2	5.567602⏨ 0	1.194185⏨ 0
31	4.058668⏨ -2	1.396336⏨ -2	6.247134⏨ 0	8.448647⏨ 0
36	6.749538⏨ -1	4.526216⏨ -2	8.416940⏨ 0	2.223707⏨ 2
0	1.463950⏨ 0			

NALYSIS OF VARIANCE TABLE

	SUMS OF SQUARES	DZZ.FZZ.	MEANZZ SQUARESZZ	FZZ-RATIOZZ
UE REGRESSION	1.365087⏨ 1	4	3.412718⏨ 0	5.282527⏨ 2
ESIDUAL	1.162870⏨ -1	18	6.460388⏨ -3	
OTAL(CORRECT)	1.376716⏨ 1	22		

R SQUARED	R-BAR SQUARED	R
0.991553	0.989676	0.995768

ON-NEUMANN RATIO 1.623987⏨ 0

ARIANCE-COVARIANCE MATRIX

8.106⏨ -4	-2.770⏨ -4	1.533⏨ -6	-2.309⏨ -4	23
	2.426⏨ -3	-4.110⏨ -4	-1.807⏨ -3	26
		1.950⏨ -4	2.451⏨ -4	31
			2.049⏨ -3	36

ORMAL MATRIX

1.000	0.652	0.312	0.642	0.105
	1.000	0.580	0.874	0.046
		1.000	0.410	0.231
			1.000	0.100
				1.000

APPENDIX II

The estimates of the restricted production function.*

The restricted Cobb-Douglas production function is incapable of reflecting increasing and decreasing returns to scale since it implies the assumption of constant returns. It was due to this limitation that Douglas (1948) abandoned its application in favour of the unrestricted form. However, from a statistical point of view, the use of the restricted form is still attractive for the following purposes.

a) In the case of the existence of a strong multicollinearity amongst the explanatory variable due to high correlation, a reduction in the degree of multicollinearity and hence an increase in the order of the inverse of the matrix of the explanatory variables is likely to result from deflating through by one of the explanatory variables (see section H of chapter XI).

b) If it was the case that multicollinearity was due to the view that all the variables were dependent on the (arbitrary) size of conventionally defined industries, then deflating through by labour, e.g., would reduce greatly such multicollinearity.

c) In the case of the need to test the significance of increasing or decreasing returns to scale reflected by the unrestricted form, it is necessary to estimate the sum of squares of the residuals of the restricted form (see footnote 1, page145).

d) In the case of the availability of a few number of degrees of freedom, thus the use of the restricted form allows one degree of freedom to be saved.

The restricted form estimates are given by Table (II.1) for the net output and gross output functions. Investigating these estimates reveals a startling consistency with the estimates of the

---

*"Restricted" in this cotext means all variables have been deflated by labour.

TABLE (II.1)

Estimating the Restricted Cobb-Douglas Production Function

Eqn. No.	Dept.	Capital All	Capital Modern	Capital Older	Degree of Capacity Utilisation	Output Elasticity with respect to Total	R & D_{62}	R & D_{56}	F	M	Inter-mediates	R^2	$\bar{R}^2$
1	lnNO	0·306 (0·048)										0·658	0·642
2	lnNO	0·313 (0·039)			8·735 (2·544)							0·785	0·764
3	lnNO		0·450 (0·063)	-0·165 (0·067)								0·839	0·823
4	lnNO	0·406 (0·052)	-0·113[a] (0·056)	6·373 (1·827)								0·902	0·887
5	lnNO	0·254 (0·055)					0·0440[a] (0·0251)						
6	lnNO	0·247 (0·053)						0·0468[a] (0·0231)				0·716	0·689
7	lnNO	0·253 (0·057)				0·0510[b] (0·0326)						0·696	0·665
8	lnNO	0·242 (0·063)							0·0599[b] (0·0395)			0·694	0·663
9	lnNO	0·277 (0·056)								0·0324[c] (0·0320)		0·675	0·643
10	lnNO	0·281 (0·047)			7·917 (2·592)		0·0273[c] (0·0218)					0·802	0·770
11	lnNO	0·274 (0·045)			7·708 (2·552)			0·0308[b] (0·0202)				0·809	0·779
12	lnGO	0·139 (0·046)									0·628 (0·065)	0·973	0·970
13	lnGO		0·202 (0·042)	-0·0930[a] (0·0491)							0·653 (0·039)	·984	0·981
14	lnGO	0·150 (0·040)			4·236 (1·539)						0·619 (0·041)	0·981	0·978
15	lnGO		0·184 (0·039)	-0·0611[b] (0·0467)	3·048 (1·344)						0·642 (0·036)	0·987	0·984
16	lnGO	0·0534[c] (0·0479)					0·0408 (0·0135)				0·677 (0·043)	0·982	0·979
17	lnGO	0·0807 (0·0467)						0·0320 (0·0127)			0·652 (0·043)	0·980	0·977
18	lnGO	0·0687 (0·0502)				0·0433 (0·0179)					0·660 (0·044)	0·979	0·976
19	lnGO	0·0846 (0·0521)							0·0410[a] (0·0220)		0·642 (0·045)	0·977	0·974
20	lnGO	0·0897 (0·0515)								0·0322[a] (0·0182)	0·655 (0·047)	0·977	0·973

TABLE (II.1) (Contd.)

Eqn. No.	Dept.	Capital All	Capital Modern	Capital Older	Degree of Capacity Utilization	Output Elasticity with respect to: Total	R & D_{62}	R & D_{56}	F	M	Intermediates	R^2	$\bar{R}^2$
21	lnGO	0·0800 (0·0453)			3·149 (1·436)		0·0320 (0·0130)				0·659	0·986	0·982
22	lnGO	0·104 (0·044)			3·369 (1.493)			0·0242[a] (0·0121)			0·639 (0·039)	0·984	0·981

(a) Significant at the 10% level

(b) Significant at the 20% level

(c) Significant at the 30% level.

unrestricted form. The aspects of this consistency are summarised by Tables (II.2) for the net out-put function and Table (II.3) for the gross output function. In both tables the comparison is drawn between the coefficients, the standard errors, and the amount explained of the residual upon improving the specification of the input factors and the production function itself.

Tables (II.2) and (II.3) reflect a close agreement between the estimates of output elasticity with respect to all capital assets, modern stocks of capital, older stocks of capital, the degrees of capacity utilization and the research and development personnel for the restricted and unrestricted forms. These estimates, thus, extends the findings of chapter VI, with respect to the restricted and unrestricted forms of the traditionally specified production function, to the more accurately specified inputs and functional relationships.[1]

Table (II.1) indicates a large difference between the $\bar{R}^2$ of the unrestricted and restricted net output function. Nevertheless, there is a close agreement between the percentage of the residuals explained by: drawing a distinction between modern and older stocks of capital; introducing a correction for the degree of capacity utilization, and the explicit introduction of the research and development personnel in the specification of net output functions (see Table II.2).

Table (II.3) on the other hand reflects a much smaller difference between the $\bar{R}^2$ of the unrestricted and restricted gross output functions as compared with their counterpart net

---

1. See p. 142, ff.

TABLE (II.2)

A Comparison between the Estimates of the Restricted and Unrestricted forms of Net Output Function

Equation No.		Output Elasticity with respect to All Assets		Modern Assets		Older Assets		Degree of capacity utilization		Percentage explained of the first equation's residual	
Restd.	Unrestd.	Restd.	Unrestd.	Restd.	Unrestd.	Restd.	Unrestd.	Restd.	Unrest.	Restd.	Unrestd.
II.1.1.	6.1.4	0·306 (0·048)	0·324 (0·049)								
II.1.3	6.1.8			0·450 (0·063)	0·456 (0·069)	-0·165 (0·067)	-0·175 (0·079)			50·6	47·4*
II.1.2	8.1.2	0·313 (0·039)	0·328 (0·040)					8·735 (2·544)	8·443 (2·518)	34·1	31·6
II.1.4	8.1.12			0·406 (0·052)	0·411 (0·057)	-0·113 (0·056)	-0·120 (0·065)	6·373 (1·827)	7·220 (1·926)	68·4	67·5
				R_{62}		R_{56}					
				Restd.	Unrestd.	Restd.	Unrestd.				
II.1.5	11.4.1	0·254 (0·055)	0·272 (0·055)	0·0440 (0·0251)	0·0440 (0·0246)					8·9	11·0
II.1.6	11.4.2	0·247 (0·053)	0·262 (0·053)			0·0468 (0·0231)	0·0491 (0·0212)			13·1	18·4

---

*For instance the percentage explained of the residual of the traditionally specified function (6.1.4) due to correcting for the vintage of capital by (6.1.8) is calculated as

$$\frac{(1-\bar{R}_a^2) - (1-\bar{R}_b^2)}{(1-\bar{R}_a^2)} \times 100$$

where the subt. a and b refer to the two equations respectively.

$$= \frac{(1-0.962) - (1-0.980)}{(1-0.962)} \times 100$$

$$= 47.4\%$$

output functions. Again the close agreement between the various output elasticities as estimated by the restricted and unrestricted gross output functions is startling. Moreover the percentages explained of the residual due to improving the specification of inputs and the gross output function by the restricted and unrestricted forms are very close.

The main conclusion which can be derived from Tables (II.1)-(II.3) is that the findings of the present study do not seem to be influenced by the official classification of the studied manufacturing industries. In other words the conclusions based on the results of this study would be the same had the classification of industries been different.

TABLE (II.3)

A Comparison between the Estimates of the Restricted and Unrestricted Forms of Gross Output Function.

Equation No.		Output Elasticity with respect to						Degree of capacity utilization		Percentage explained of the underlined equation	
		All Assets		Modern Assets		Older Assets					
Restd.	Unrestd.	Restd.	Unrestd.	Restd.	Unrestd.	Rest.	Unrestd.	Restd.	Unrestd.	Restd.	Unrestd.
II.1.12	6.1.6	0·139 (0·046)	0·139 (0·047)								
II.1.13	6.1.7.			0·202 (0·042)	0·236 (0·041)	-0·0930 (0·0491)	-0·136 (0·048)			36·7	50·0
II.1.14	8.1.6	0·150 (0·040)	0·150 (0·040)					4·236 (1·539)	4·366 (1·568)	26·7	26·4
				R_{62}		R_{56}					
				Restd.	Unrestd.	Restd.	Unrestd.				
II.1.16	11.4.10	0·0534 (0·0479)	0·0538 (0·0493)	0·0408 (0·0135)	0·0406 (0·0140)					30·0	28·5
II.1.17	11.4.10	0·0807 (0·0467)	0·0735 (0·0469)			0·320 (0·127)	0·334 (0·122)				

APPENDIX III

The treatment of the most relevant sources of statistical bias it is stated in Chapter V is in line with Thiel (1958) if the correctly specified relationship is:

(6.23) $$y = X_1 \beta_1 + u_1$$

and the wrongly specified relationship is:

(6.24) $$y = X_2 \beta_2 + u_2$$

"First, it was observed that the specification (6.24) as such has been hardly defined, in particular, β_2 is not defined. So we are entirely free in defining; and we shall interpret β_2 as the mean value of the least-squares expression $b_2 = (X_2'X_2)^{-1}X'_2y$. In that case β_2 can be easily shown to be equal to

$$\beta_2 = P\beta_1$$

where P is the coefficient matrix of the least-squares regressions of the correct explanatory variables on the erroneous ones:

$$X_1 = X_2P + \text{least-squares residuals}"^1$$

" Applying least-squares to (6.24), we find

(6.110) $$b_2 = (X_2'X_2)^{-1}X_2'y = (X_2'X_2)^{-1}X_2'X_1\beta + (X_2'X_2)^{-1}X_2'u$$

Taking mean values on both sides gives

$$\mathcal{E}b_2 = P\beta_1 \text{"}^2$$

---

1 Theil, H. Economic Forecasts and Policy, North-Holland Publishing Company, Amsterdam, 1958, page 213.

2 Ibid p. 326.

"This result, though very simple, is of wide applicability in econometric analysis. .... Suppose that (6.24) contains the same number of variables as (6.23), both being fully equivalent except for one variable; i.e., the last column of X_1 differs from the corresponding column of X_2. .... In such a case the two β 's have an equal number of components and even an identical economic meaning for all components except the one corresponding to the above mentioned variable. Still it can be shown that in general all components are affected by the incorrect specification. For the matrix P, which is square in this case, will now be unit matrix except for the last column, and this column will generally consist of non-zero elements.

Hence:

$$(\mathcal{E}b_2)_\lambda = \beta_\lambda + p_{\lambda\Lambda}\beta_\Lambda \quad *$$

where $(\mathcal{E}b_2)_\lambda$ and β_λ are the λ-th components of $\mathcal{E}\,b_2$ and β_1 respectively, and the p's are the coefficients of the auxiliary regression

$$x_\Lambda(t) = \sum_{\lambda=1}^{\Lambda-1} p_{\lambda\Lambda}x_\lambda(t) + p_{\Lambda\Lambda}x'_\Lambda(t) + \text{residual} \quad *$$

x'_Λ being the substitute for the variable x_Λ. The difference $(\mathcal{E}b_2)_\lambda - \beta_\lambda = p_{\lambda\Lambda}\beta_\Lambda$ may be called the specification bias of the coefficient $(\mathcal{E}b_2)_\lambda$."[1]

"Secondly, specification analysis can be used for the treatment of errors of measurement (or errors of observation). .... If there is no correlation among the explanatory variables, the least squares

---

[1] Ibid. pp. 326 and 327.

* The two equations above are close to (5.8) & (5.9) in the text. It is to be noted that β_Λ is the last coefficient of the vector β_1 of (6.23) (see p. 315).

parameters are biased towards zero; and if there is such a correlation, this effect tends to be even worse ......"[1]

The Applied Tests

The equal-tails "t" test is used to test the significance of the estimated and discussed coefficients. Unless otherwise mentioned the traditional 5 per cent level of significance is considered, e.g.,

$$t_{(.05,\ n-m)} = \frac{\text{Coefficient}}{\text{S.E.}}$$

where n - m is the number of degrees of freedom.

If the table of "t" is one-sided tail then t(.025, n-m) should be compared with the computed "t".

Only in the case of testing the significance of the difference between two coefficients, especially in the case of testing the significance of the difference between males and females elasticities, the one-sided tail "t" test is used as follows:

$$t_{(.05,\ n-m)} = \frac{a_1 - a_2}{\sqrt{\text{Var.}a_1 + \text{Var.}a_2 - 2\text{Cov.}\ (a_1,\ a_2)}}$$

where a_1 and a_2 stand for the elasticities of males and females respectively.

For the equation

$$NO = f(L_m,\ L_F,\ K_A,\ A)$$

where NO, L_m, L_F and K_A stand for net output, males, females and net stocks of all fixed assets, and A is a residual term.

[1] Ibid. P. 214.

In order to test the hypothesis that the elasticity of L_m is larger than the elasticity of L_F, the null hypothesis is that the elasticity of L_m = elasticity of L_F. If the difference is positive and statistically significant, the null hypothesis must be rejected. The Computed "t" for British manufacturing industries is

$$t_{(0.05,\ 19)} = \frac{0.542 - 0.223}{\sqrt{0.00354 + 0.00121 - 2(-0.000866)}}$$

$$= \frac{0.319}{\sqrt{0.00648}}$$

$$= 3.98$$

since the tabulated one sided tail $t_{(0.05,\ 19)}$ is 1.729, the null hypothesis is rejected.